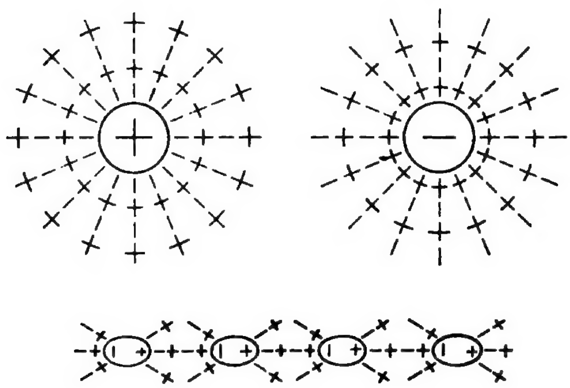
ELECTRICITY

THE

CHEMISTRY OF ETHER



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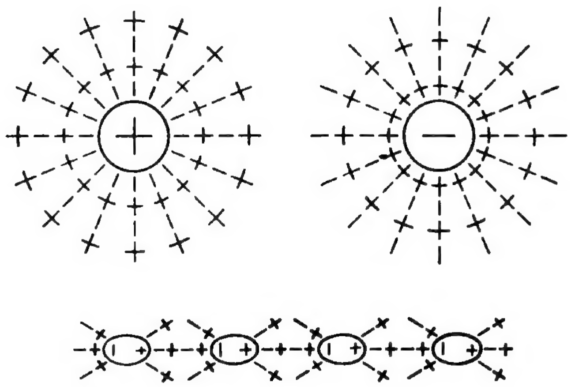

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ELECTRICITY

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A TREATISE

Generalizing a Fundamental Hypothesis as applied to Electricity, Chemistry, Physics, Physiology, and Pathology, with chapters on General and Gynecological Electro-Therapeutics.

BY

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Illustrated by 134 Engravings and Containing Tabulations of Polar Differentiations, and of Current-Comparisons.

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To

His Wife

ALICE DOUGLAS ADAM,

In

Grateful consideration of the assistance and encouragement rendered in its preparation,

This

Book is Affectionately

Inscribed,

By

The Author.

PREFACE

The basic conceptions of this work are: That matter is composed of two units quantitatively equal but qualitatively opposed; that these are found in their simplicity in electric potentials; and that the one unit partakes of the character of a positive electric potential, and the other of a negative electric potential. From these conceptions follows the formularization of the hypotheses that: *Ether is the simplest form of matter;* and *Electricity is its Chemistry.*

The author to the best of his ability has kept to the text—wherever the hypotheses have *led* he has followed—giving due weight to all facts, but not hesitating to brush aside accepted theories, or correct accepted laws, when these have barred the way. In a generalization all facts must be explained. A single contradictory fact destroys an hypothesis, no matter how many support it. This axiom has been constantly borne in mind, and by it the merit of the work is measurable. The author has an abiding faith in the correctness of his hypotheses, but is aware that in many details his reasoning may be defective. The manner of arriving at certain conclusions may be considered arbitrary; but a theory that aims at a generalization, and meets no contradictory facts, should be the arbiter by deduction in the solution of some problems. For six years the author has taught his medical classes that electricity is the chemistry of ether. To his students this postulate is as familiar as the atomic theory. This

work therefore is presented after mature consideration of the principles embodied.

The author believes that the numerous facts adduced are evidences of the law of attraction and repulsion as formulated. He particularly invites attention to the addenda in which various facts and phenomena are explained by, and hence, conversely, support the correctness of the formularization. Hitherto it has been a scientific dogma that a molecule could never be seen, and it is almost iconoclastic to announce that certain molecules can be perceived and measured by means of the microscope; but the study of the definition of a molecule, and of the relative facts noted, particularly those connected with division of the centrosome, is convincive of the truth of the announcement.

The reader will bear in mind that conclusions arrived at are deductions based upon the fundamental hypotheses (which he is asked to accept provisionally), and upon established facts; also, that this work being a treatise generalizing fundamental principles, each successive part of it rests on the preceding. The author is fully aware that many accepted theories contradict his hypotheses, and his conclusions. Critically it may be said that this work is merely theoretical and unsupported by laboratory evidence. On the contrary, the author has not consciously failed to examine any fact the consideration of which might modify deductions, but often he has formulated conceptions without at the time being acquainted with relative facts. A notable instance of a concept formulated by deduction is as follows: In the earlier consideration of this subject it was concluded that the anisotropic substance must be a molecule with an induced field, and its area was defined as extending to the middle of each adjoining isotropic

substance. Later physiologic works have defined the sarcomere, with such boundaries.

The author embraces this opportunity to thank Dr. Samuel O. L. Potter for courtesies which led to a special study of the subject-matter of this work. He expresses his appreciation for assistance given by Dr. E. M. Paterson in reviewing manuscripts and discussing principles. He is indebted to Dr. Frederick W. Lux for courtesies leading to valuable hints in preparing the text; and to Dr. George P. Wintermute for execution of an original drawing, and for assistance in proofreading.

It is a pleasure to refer to the following works which the author has used as text-books in his lectures, from which he has gleaned facts noted in this volume; or from which he has received contributions toward illustrating his concepts: "Practical Electricity in Medicine and Surgery," Liebig and Rohé; "Medical and Surgical Electricity," Rockwell; "An International System of Electro-Therapeutics," Bigelow-Massey; "Conservative Gynecology and Electro-Therapeutics," Massey; "The Treatment of Disease by Electric Currents," S. H. Monell; "Physiology of Man," Flint; "The Anatomy of the Central Nervous System," Gordinier; "The American Text-Book of Physiology"; "The Nervous System," Barker; "Manual of Physiology," Stewart; "Human Histology," Sobotta, edited by G. Carl Huber; "Histology Normal and Morbid," Dunham; "Elementary Lessons in Electricity and Magnetism," Sylvanus Thompson; "Normal Hystology," Piersol.

SAN FRANCISCO, January 1st, 1904.

EMENDATIONES.

Page 32, line 7, read: The components of E, or those of F being

Page 76, line 1, after "intrinsically" place a :

Page 218, line 15, read: attraction *or* repulsion.

Page 363, line 3, read: *material* for "materials."

Fig. 88, page 257, in caption substitute *Propagation* for "Polarization."

Page 600, lines 7 and 9, transpose "α" and "β," and after the paragraph read: A stream of negative matter positively electrified (negative chips of oxygen as anode rays) may emanate from the positive pole of the radio-active substance, and may constitute rays "α." (§136, §144, Fig. 60, Fig. 65). Evidently the end-products are: Metal-chips from cathode; negative oxygen chips from anode; residual oxygen particles (positive?); ether as light waves; these modified by chemical reactions.

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INTRODUCTORY SUMMARY

1. The conception that all facts, whether electric, chemic, physical, physiologic, or pathologic in character, are based upon the same fundamental principles and are therefore related, leads to the formulation of the following propositions as a statement of factors of differentiation in forms of matter or forms of force, as manifested in natural phenomena:

1. That ether is the simplest form of matter; that it is molecular, and that it has a chemistry (Fig. 1, A).

2. That electricity is the chemistry of ether—that dissociation and association of ether atoms or units constitute electricity in the broadest sense of the term (Fig. 1, B).

3. That the ether-unit or atom termed positive represents a unit of matter characterized by inherent attraction, and the ether-unit termed negative represents a unit of matter characterized by inherent repulsion; that these are the units of all matter and all force; that their differential characters are best studied under the simplicity of electric potentials; and that ether-units or atoms are definite, and may be

defined as the ultimate quantities of matter or force which no other force can split up—specific quantities of opposite quality essential to equilibrium.

4. That as all forces are reducible to the ultimate principles of attraction and repulsion, they are subject to the following fundamental law: Units of attraction (positivities) mutually attract; units of repulsion (negativities) mutually repel; and units of attraction and units of repulsion are attracted, mutually neutralized, and in maximum contact are at zero potential.

5. That the law of forces may be generalized, from Newton's law of gravitation, as follows: Any two quantities of matter, with constant media, *attract or repel* each other, with a force which varies inversely as the square of the distance (§ 101, § 30).

6. That as the ether molecule consists of a positive and a negative unit neutralized by maximum contact (Fig. 1, A), the factor of distance is reduced to its minimum as regards the application of the law of forces; on the other hand, in a more complex molecule, as shown by the property of polar differentiation, owing to relative placement each unit is not in maximum contact with its opposite; hence the immolecular distances between neutralizing forces are greater than in the ether molecule and allow exmolecular forces to take possession, and hence the ponderable molecule (§ 30), (Fig. 1, C, G, H, I). This is equivalent to the conception that constituent aggregations of matter or of force, of the same quality, are larger in the ponderable than in the ether molecules.

7. That units of attraction are manifested as concentrativeness, and units of repulsion as diffusibility; that matter and force in relation to space are in equilibrium, which is maintained by the formation of

ponderable molecules with differential qualitative and quantitative potentials and corresponding induced fields (Fig. 1, E, H), and by ether molecules of definite dimensions, without potentials and without induced fields; and that as a concomitant to the equilibrium all space is occupied.

8. That the great principle of induction universally accompanies primary potentials whether electric or molecular; that it is essential to the equilibrium or neutralization of forces; that as primary forces mutually react inversely proportional to the square of distance, so induction increases as the reaction between primary forces decreases; that it varies inversely as the dielectric constants of media; that it is reactive on the primary potentials; and is subject to the law of forces (§ 19, § 65).

9. That matter and force are impenetrable; moreover, induced force is impenetrable. Hence the law "that units of attraction mutually attract" is modified by the property of impenetrability of positively induced fields to like forces (§ 23).

10. That all forces are neutralized, and that the factor of distance is the essentiality of potential. The forces of an ether molecule are neutralized immolecularly through its units being in maximum contact; those of a ponderable molecule: (1) immolecularly, (2) by the potentials of other molecules or masses, (3) by the creation of induced potentials (§ 26).

11. That electric potential and chemic potential are fundamentally identical, being based on inductively free ether-units or atoms; differentiating in as much as in the former the ether-units are completely free,* and

* The term free is used to designate units not neutralized within the potential-location and which constitute inductive potential. The inductive

in the latter are constituents of, and are partly neutralized within, the chemic atom (Fig. 1, B, C).

12. It follows that there is an analogy between electric manifestations and molecular conditions, and that a study of the one will enable us to define the other (Fig. 1, D, E). Consequently the following definition of a ponderable molecule must be accepted: That it is the ponderable physical unit; that its ultimate constituent units are identical with ether atoms; that it has a potential of extrinsically neutralized units of positive or negative quality; that this potential is represented in an induced polarized field surrounding the molecular body, and therefore may be termed the *inductive potential;* that this tridimensional induced field is the free or vibratory molecular space; and that there are no free spaces within the molecule, the units being in direct contact and more or less immolecularly neutralized (Fig. 1, C, E), (§ 26).

13. That chemic atoms are groups of ether-units, that they associate and dissociate in obedience to their quantitatively and qualitatively differentiated potentials represented by the extrinsic neutralization of their units; that within the molecule they are more or less neutralized through direct contact with other chemic units, and they therefore have no free surrounding spaces, and consequently lose their identity in the molecular construction (§ 18, § 26.)

14. That atomic and molecular states are mutually transformable: At a specific decrement of pressure an atom dissociates and assumes the molecular condition; and at a specific increase of pressure a molecule

potential of a molecule is the number of units not neutralized within the molecule, and is the difference between the sum of its positive and the sum of its negative units; and the inductive potential of an electric charge is the number of units not neutralized within itself, and is the total charge.

will unite with another molecule, although qualitatively the same in potential, the constituents of the nascent molecule having a common induced field (§ 34); that dissociation is progressive until ultimate ponderable molecules are reached (§ 143, § 18), and in general is according to a fixed law: The dimensions of molecules decrease and their potentials and induced areas increase in inverse proportion to pressure and in direct proportion to temperature.

15. That the dimensions of molecules decrease and their potentials and induced fields increase inversely as the sum of their constituent negative units and directly as the sum of their positive units. This law is evidenced by the relative sizes of molecules in a vacuum tube, and by the relative sizes of the molecules of oxygen and hydrogen, but it may be modified by conditions belonging to the solid and liquid states (§ 29).

16. That magnetism is polarization of a molecular potential depending on the relative placement of ultimate constituent units. It is the connecting link between electric potential and the differentiated potentials of molecules, and shows ther ultimate identity (§ 68).

17. That the transformation from chemic force to electricity, heat, or light, is accomplished through the setting free of ether from the induced fields of ponderable molecules, concurrent with the reciprocal rearrangement and further immolecular neutralization of their atoms (§ 41, § 42); that the transformation from electricity to heat and light is by atomic ether becoming molecular; that heat and light are a disturbance of the equilibrium between ether and other matter caused by freed or nascent molecular ether, and manifested by waves of readjustment (§ 103, § 126).

18. That crystallization is the great physical analogue of physiologic action (Fig. 1, G, I), having the following factors: Molecular polarization; equipotential hemispheres of the molecule when polarized; association of other molecules in order that the hemispheres should be equipotential—absorbing water of crystallization; and the dissociation of these additional molecules —dehydration—on molecular depolarization (§ 148).

19. That the physiologic unit is molecular in character, having an inductive potential of negative quality, and surrounded by a tri-dimensional induced field in which are polarized ponderable molecules (Fig. 1, H); that it has the property of differentiating its poles—polarization—(Fig. 1, I) and associating molecules in order that its hemispheres be equipotential and dissociating these molecules on depolarization (§ 159).

20. That physiologic phenomena are based upon the fundamental principles of attraction and repulsion, and that they are manifested through the secondary principles of *molecular potentials*, *molecular induced fields*, *and molecular polarization* (§ 154).

21. That the molecular conception of the physiologic unit leads us to formulate the following law: That the physiologic unit at rest is in the electric state, with a uniform induced polarized field (Fig. 1, H); and that in action it is in the magnetic state, with differentiated poles and differentiated induced polar fields (Fig. 1, I).

22. That the potentials of molecules must be estimated on the basis of constituent ether-units, and not on that of chemic atoms. Thus, water, having 16 parts of negative oxygen and 2 parts of positive hydrogen, is apparently electronegative, but a qualitative estimation of ether-units in the atoms of oxygen and hydrogen shows water to be electropositive, and this accords with

the physical character of water and its behavior under electric currents (§ 60, § 36).

23. That waves of contractility or conductivity are propagated by the induced polar field of one physiologic unit stimulating the succeeding; that as the leading-off point of each wave is negative, there is a positive stimulus within the structure to each unit, excepting the initiatory; and hence natural initiatory stimuli are positive (§ 174, § 234), or neutral.

24. That inhibition is accomplished by an *efferent impulse through an afferent nerve*—a reverse polarization which partially or wholly takes possession of the initiatory field, thus delaying or preventing the afferent impulse; and that reversed polarization may be caused by negative stimuli (§ 264).

25. That at the moment of depolarization there are dissociated at the poles of the physiologic unit an extreme positive and an extreme negative atom—ions—the courses of which differ; and that the dissociation constitutes the waste of the unit (Fig. 1, K). (§ 160).

26. That *ions* are dissociated constituents (chemic atoms) of a molecule, which have assumed the molecular condition with subnormal dimensions and supernormal potentials, measured by the standard of the environment (§ 54, § 160).

27. That the nutritive elements of the physiologic unit must be identical with its waste elements, although differing in potential; and that the unit receives molecular nutrition qualitatively the same in potential as its own, and hence the union must be accomplished by extrinsic pressure. Hence the formula: The unit during rest associates molecules as nutrition, and during action dissociates them as ions (§160—163).

28. That fundamentally physiological units are iden-

tical, only quantatively differing in potential; and that functional differentiation is accomplished by the differentiation of environment.

29. That *potential-carriers* are classified thus: (1) Molecules which under specific pressure and temperature have their dimensions increased by the addition of other molecules or ions of the same quality, the added elements being unloaded under different conditions; (2) molecules of high potential attracting other molecules of opposite quality to their induced fields without chemic reaction until changed conditions favor combustion (§ 159).

30. That ions produced by gland-cell action are impressed into blood elements, and build up the latter in potential, which become *potential carriers*, returning to the circulation through lymph channels (as in the thyroid), or forming the principal constituents of an internal secretion (enzymes, etc.) (§ 203—216).

31. That electropositive blood-elements of high potential, as potential-carriers, during respiration absorb oxygen into their induced fields, and that under specific degrees of temperature and pressure combustion takes place between the potential-carriers and the oxygen (§ 159). Hence the nutrition of tissues.

32. That the principle of insulation obtains in physiology as in electricity and is based on the specific dielectric qualities of media (§ 179).

33. That osmosis is qualitatively differentiated by the polarity of tissues, especially of the glands, thus determining the character of secretions, etc. (§ 225).

34. That a classification of cells may be made on the basis of their nutrition: (1) The nutritive elements may be similar to the constituents of the cell giving it the power of reproducing itself; (§ 243); (2) they may

be more positive than the constituents, with the result of reproducing a more positive cell-unit (§ 233); (3) they may represent a limited number of the cell-constituents, negative as a molecular group, with non-interference with the basic portion of the unit, whilst they associate as nutrition and dissociate as waste (§ 160); (4) the associating elements may be ions produced by the action of other cells, no immediate dissociation taking place (§ 230).

35. That the following factors qualify cell nutrition: (1) The starting point and destination of osmosis—from blood or lymphatic vessels to lymphatics, tubules, cavities, or surfaces; (2) the differential polarity of surrounding cells or structures qualifying osmosis; (3) ions produced by adjoining cells acting directly on the cell or on the osmotic stream; (4) degrees of pressure and temperature.

36. That any physiologic cell by change in the character of nutrition may become pathologic, with or without reproductive properties (§ 240, § 301).

37. That there is *a vibratory balance* of molecules having the following factors: Molecular weight; inductive potential; free space or vibratory field; pressure and temperature. That vibratory interception or origination in any molecule has specific limits of frequencies which are modified by variation in any of the above factors (§269—288).

In Fig. 1 the symbols + and − represent units of matter and units of force, quantitatively equal but qualitatively opposed; A, represents a molecule of ether, in which the units are immolecularly neutralized, hence it is potentially at zero; B, the positive and negative units separated, and the signs respectively represent positive and negative electrifications; C, C[1], positive and

negative primary molecules of ponderable matter, each being equal in potential to a free unit of ether, or an ultimate unit of electricity—in the vacuum tube similar molecules have been demonstrated to be carriers of

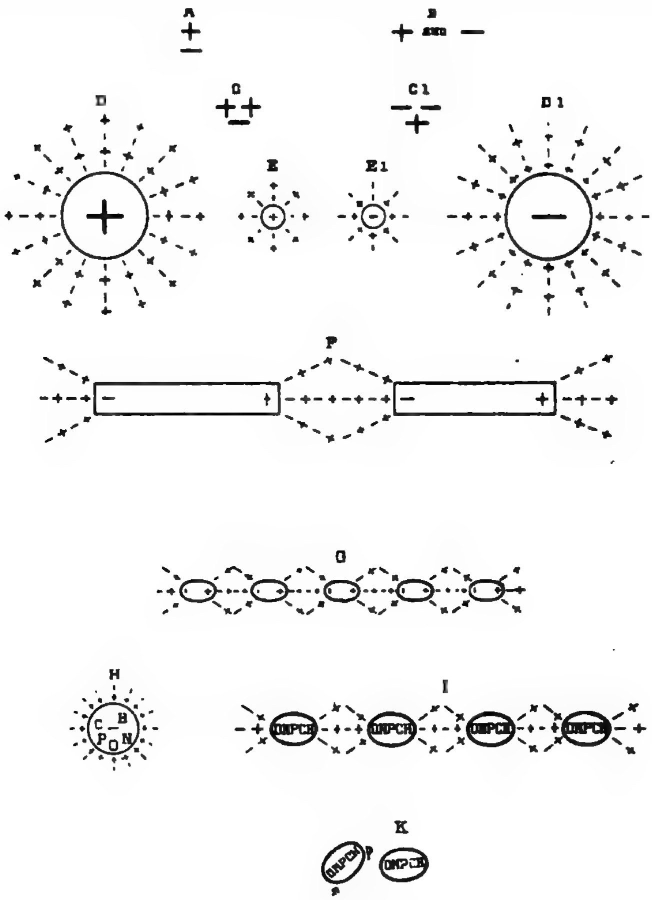

Fig. 1.
Potential Differentiations.

electricity, and to be one thousandth the mass of the hydrogen atom; D^1, D, differentially electrified bodies with uniform induced fields, the induction being demonstrable by placing a conductor within the field; E, E^1,

molecules of ponderable matter, surrounded by tridimensional induced fields or free vibratory spaces; F, magnets with differential polar induced fields, also demonstrable; G, molecules of a magnet with differentiated polar induced fields; H, the physiologic unit at rest, potentially of negative quality, and surrounded by a uniform induced field; I, the physiologic unit polarized or in action, with differentiated poles and differentiated induced fields—they are in a state of tetany, coagulation, crystallization, etc.; K, a physiologic molecule depolarizing, with p and n representing ions dissociated at their respective poles. Specifically, the p represents hydrogen and carbon, and n represents oxygen, respectively the most positive and negative chemic constituents of the physiologic molecule. C and C' are representative of ultimate ponderable molecules, or the ultimate tenuous condition or limit of dissociation of ponderable matter; whilst H is representative of extreme association of ultimate units in the construction of the molecule. The symbols, + and −, represent ether-units, but in the induced fields of electrically charged bodies, and in those of physiologic units, they, in addition, represent polarized ponderable matter. The components of the figure may be classified as representations of *rest* (electric state), and *action* (magnetic state)—*pax et strenuitas.*

PART I

ELECTRO-CHEMISTRY AND ELECTRO-PHYSICS

CHAPTER I

FUNDAMENTAL PRINCIPLES

2. Electricity, Chemistry, Physics, and Physiology present numerous problems which must be solved by the formularization of laws fundamental to all. The generalization must embrace all facts. Principles which are ultimate must be component units of all laws, and a law that has exceptions to its applications cannot be fundamental. A hypothesis must lead to the explanation of all facts of the subjects to which it pertains; one established fact contradicting the hypothesis is destructive to its fundamentality and to its correctness.

The hypothesis on which the subject-matter of this work is based is that *the ether is the simplest form of matter*—that it represents units of matter and units of force common to all matter and to all forces, and that the ether-units or ether-atoms are fundamental and ultimate. Having adopted a hypothesis our effort will be to follow it wherever it may lead, irrespective of accepted theories. The value and correctness of the

hypothesis must be determined by its adaptability to a grand generalization of facts. The provisional acceptance of the hypothetical truth will enable us to formulate other conceptions which by deduction must necessarily follow.

The Fundamental Laws of Electricity are well understood, and through these its study should be approached, for a law on which depends an infinite number of facts can be more easily comprehended than the facts. The science of electricity is more simple than chemistry, for whereas in chemistry we have over seventy elements to deal with, the ultimate property of each of which is doubted even by the chemist himself, in electricity we have only two, and these are ultimates which have no analyses. The boundary between the knowable and unknowable in electricity has been pushed back as far as that of any other science, and it is incorrect and unscientific to say that electricity is a "mysterious element."

The medium of manifestation of the interchangeable forces heat, light, and electricity is ether, a universally present substance, existing in two forms, the *molecular* and *atomic*, just as other matter exists, differentiating only as to conditions.

Molecular ether is interstellar and intermolecular in relation to ponderable matter, and forms an ocean in which ponderable molecules and masses float. Moreover, the atoms or units of ether are immolecular—are identical with, if not interchangeable with the unit-constituents of the ponderable molecular body. The conceptions of the character of ether follow the acceptance ot the hypothesis that it is a fourth state or the simplest form of matter, supplementing the three forms—solid, liquid, and gaseous. Ether, like the

other forms of matter being molecular, must have a chemistry.

Electricity is the chemistry of ether. In the chemistry of ponderable matter the known elementary substances are numerous, but relatively they belong to two classes, designated positive and negative, and science may succeed in reducing these elements to two, which will be identical with the chemical division of ether.

For purposes of *designation* the atoms of the ether molecule have been named *positive* and *negative*, or *plus* and *minus*, but it is to be understood clearly that these terms are symbolic and not meant to characterize the properties of the ether atoms. All electric, chemic, and physical facts have as a fundamental principle attraction or repulsion. It follows that there is a unit ot attraction and a unit of repulsion which must be represented by ultimate units of matter. Hence ether, being the simplest form of matter, must have units representing the ultimate principles of force. This conception is supported by there being qualitatively only two electric potentials, termed positive and negative. Hence we postulate: *That the positive unit of ether represents a unit of attraction, and the negative unit of ether a unit of repulsion, and that these are the ultimate units of all matter and of all force.*

Experiment has shown that certain forces, acting on the molecules of ether, separate their atoms, which under favorable conditions remain apart, and under other conditions reunite. *The province of electric science (electricity) embraces a study of the phenomena attending the dissociation of the atoms of ether molecules, and the reunion of the atoms to form molecules.* This definition of electricity is analagous to that of chemistry, and broadens the term.

3. Friction between the surfaces of certain substances, such as rubbing a piece of glass on a stick of resin, will break up ether molecules into elementary atoms, and those which have been conventionally named *positive* will adhere to the glass, and the other—conventionally named *negative*—will attach themselves to the resin. The glass and the resin are then in a state of electrification, and have newly acquired or additive properties.

4. It is found that similarly electrified bodies recede from each other, and dissimilarly electrified bodies are attracted; accordingly it has been formulated as a law that *likes mutually repel and unlikes mutually attract.* That "likes mutually repel" is not of universal application, as shown by the concentrativeness of positive electric currents, and gravity attraction between electropositive masses (§ 28). It may be stated here that the mutual repulsion of positively charged bodies may be limited to the areas of induced fields of positive potentials (§ 23). This form of repulsion is in principle an impenetrability of induced force. The author formulates the following law as being in accordance with a generalization of facts: *Units of attraction (positivities) mutually attract; units of repulsion (negativities) mutually repel; and units of attraction and units of repulsion are attracted, mutually neutralized, and in maximum contact are at zero potential.* When the positive and negative atoms of ether are separated there are two elementary forces—*attraction and repulsion*—being constantly exerted to bring them together, and these two forces characterize all electric phenomena (§ 29).

5. When a body is electrified, and it is found that the electrification becomes equally distributed over its surface—that it is capable of carrying electricity, or

allowing electricity to travel from one part of its surface to another—it is called a *conductor* and the property possessed by it is called *conduction*.

When a substance retains the electrification at the point electrified, and is incapable of carrying the electricity to any other part of its surface, not having the property of conduction, or having it but slightly, it is called a *non-conductor* or *insulator*.

The property of conduction is possessed by bodies in varying degrees. The following table of substances illustrates the relative order in which it is manifested:

All metals.
Charcoal.
Dilute acids.
Saline solutions.
Water.
Living animals.

Silk.
Gutta percha.
Glass.
Wax.
Resin.
Shellac.

The substances named in the first section of the table conduct freely, while conduction is possessed by the substances in the latter section so slightly as to make them practically non-conductors. The metals have the greatest conducting power and shellac the least; the latter is therefore the best insulator.

6. The property of conduction will be more clearly understood by illustrating electrification by convection. If a number of metallic bodies be suspended by silk cords (Fig. 2) so as to swing freely and rhythmically, as

in the swing of a trapeze—each alternately touching its immediate neighbors—and one of the bodies be electrified, the electrification will become equally distributed over all of them. The ball first electrified on touching its neighbor will part with half of its electrification, the two balls becoming equally electrified.

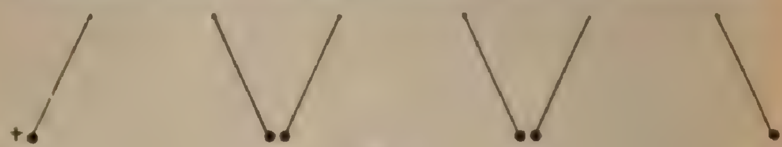

Fig. 2.
Showing Electrification by Convection.

Equalization of electrification will take place each time two balls come in contact, and the process will go on until an equilibrium of electrification occurs throughout the whole system of balls. When two balls touch and are electrified similarly they will repel each other, thus aiding the movement.

All molecules are capable of vibrating on their axes; when they do so freely and in rhythmic order, they become, when electrified, convective carriers of atomic ether until there is an electric equilibrium established, as in the case of the electrification of conductors. When the molecules are firmly set and do not vibrate or vibrate slightly, or are irregularly set and vibrate without rhythm, the ether atoms of the electrification become blocked or dammed, and the material composed of such molecules is a non-conductor.

7. In Fig. 3, the globes represent molecules of ponderable matter, and the plus and minus combined indicate the position of molecular ether, intermolecularly placed as regards ponderable matter; whilst the separate plus denotes a charge by positive electricity. Now, the atomic ether, being adherent to the

material molecule, cannot pass over the intermolecular space if not carried by the vibratory action of the molecule. To understand why the atomic ether clings to the material molecule, in preference to becoming attached to an intervening ether molecule, we have only to consider the simple construction of the ether molecule.

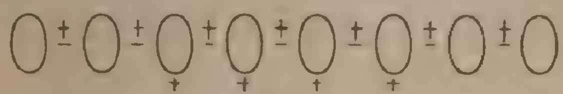

Fig. 3.
Indicating the relative positions of Ponderable Matter, Ether and Electric Potentials.

The latter is made up of a positive and negative ultimate. The forces inherent in the positive atom are fully neutralized by the forces inherent in the negative atom, and the converse is equally true. The union is elementary and complete. The principle of the one atom is fully satisfied or balanced by that of the other, and there is no free force left to attract or repel anything from without.

The complex ponderable molecule is made up of chemic atoms which are not elementary and whose properties are not entirely neutralized, the atoms themselves being condensations of varying relative amounts of positive and negative ultimates. The cause of the adherence of the free ether atom to the complex molecule has two factors—the *condensation* within the molecule, and the *partially neutralized* state of its ultimate positivities and negativities (§ 18, § 27).

The trapeziform rhythmic vibrations of the molecule are fully accounted for by the law of repulsion and attraction governing positive and negative atomic ether. The molecules when similarly loaded repel each other and at the same time they are attracted towards dissim-

ilarly loaded molecules. When unloaded or partially unloaded they naturally rebound and thus become reloaded (§ 46).

8. It is evident that if the charge as shown in Fig. 3 be surrounded by molecules incapable of the essential conducting vibratory action, the charge becomes insulated, and when in this condition it has been named *static* electricity. On the other hand, when the point of electrification is surrounded by molecular vibratory carriers, the body will become *equipotentially* charged to the extent of its non-insulation, and when moving the electrification has been termed *dynamic*.

Polarization. The term polarization when applied to molecules means that they have differential poles, and that the poles of similar quality point in uniform direction. The term when applied to a current signifies that molecules have been dissociated, and that the resulting *ions* have accumulated at the poles of the circuit.

Potential

9. By potential is meant the accumulated force—the stored energy; it represents the work done—the capital with which we start—force expended and conserved; potential is static but convertible into a dynamic force. Potential may be physical, chemic, or electric.

10. *Physical Potential* is that force which resides in a body by virtue of its relative position, or physical state. When water is at sea level its position is zero; but if it is raised as in clouds by means of the sun's rays, or pumped by the force of steam to a position above sea level, it has a potential which is equal to the force spent. The potential is lost and the force can be regained on the water returning to its physical

zero. A physical potential is also created by changing the state of matter, such as compressing a gas to a solid. This potential is the degree of departure from the physical equilibrium of matter.

11. *Chemic Potential*, or the potential of molecules, depends on the number and character of the atoms in the molecular construction. The affinity or mutual attraction of atoms rests on their positive and negative character. Positivity and negativity are the fundamental principles of all chemic action; consequently there must be a unit of positivity and a unit of negativity. These units cannot be qualified, that is, a unit being positive, cannot be more or less positive, and the same must be said of a negative unit. Again, these unit principles must be represented by unit matter. The only way, therefore, that a chemic atom can be more positive or more negative than another atom, is to have more unit principles, and more units of matter within its construction which are not fully neutralized by opposing units.

The atom of hydrogen cannot be an elementary substance, because it unites with a similar atom to form a molecule of hydrogen, which cannot occur with two positive units or two negative units, because of the fundamental law of repulsion, and because of the fundamental fact of a molecule having differential poles. The same can be said of all other so-called chemically elementary substances (§ 26).

Chemic potential is the sum of the unneutralized positivity, or the unneutralized negativity polarizable or capable of being concentrated at the pole of a molecule. It is qualitative and quantitative. For chemic potential to become fully an active force, it must approximate another molecule of quantitatively the same

or of a greater degree of potential but of the opposite sign (§1, 27).

When molecules of a substance cannot be broken up by contact with other molecules, but require such forces as heat or electricity to disintegrate them, *chemic zero* has been reached or approached. The potentials of molecules are increased by the expenditure of other forces, as in the anabolic changes of organic life, or as in the many synthetic changes that take place in the laboratory.

12. *Electric Potential* is the amount of force spent in separating ether molecules into their constituent atoms. The expended force is regained when the atoms reunite. It is the free and inherent force of separated ether atoms. The electric *zero* therefore is the neutralization of the positive and negative ether atoms in ether molecules. The absolute zero potential is the neutralization of units with maximum-contact and minimum-distance.

13. An important law governing all force is that *potentials tend towards zero*. Thus water seeks the sea level, molecules reform with less stored energy, and the electric charges of a cloud and of the earth rupture the insulating medium, and with lightning speed meet at zero.

The different potentials may be formulated thus:

Water at sea level	+	Force =	Water at a height or with a physical potential.
$(H_2O)_2$	+	Force =	$(H_2)_2\ O_2$ or increased chemic potential.
Ether $\pm$	+	Force =	+ and − or electric potential.

Electro-motive Force

14. *Electro-motive Force* is the momentum that causes the current. It is the difference of potentials—not the potentials themselves. In illustration: Two bodies of water of equal elevation have equal potentials, and therefore when connected have no flow; two quantities of oxygen gas have equal chemic potentials, and when brought together have no chemic action; so, also, when two bodies are equally electrified positively or negatively, having the same potential, when connected the electrification will furnish no current. Just as the difference in the height of water will cause a stream, and the difference in chemic potential is a cause of chemic action, so when two bodies are electrified in a different degree, or when one is electrified and the other is not electrified, or when the one is electrified positively and the other is electrified negatively, these conditions constituting a difference of electric potentials, there will be an electric current between the bodies when connected. The motive force may exist as a chemic or physical potential, convertible into an electric potential.

Electric Current

15. Current is the flow of electricity from one point to another and is the result of the electro-motive force. A current may be of long or short duration; it may be of large or small volume or of high or low tension; it may be continuous or interrupted, or may be direct or induced. A current of electricity is, in the fullest sense, the separation and reunion of ether atoms. It is analogous to analytic and synthetic chemic action.

LAW OF OHM

16. This law was discovered by Professor Ohm, of Nuremberg, in 1827. It is the basis of all electric measurement, and is expressed thus: *The current is directly proportional to the electro-motive force and inversely proportional to the resistance.* It is thus formulated:

$$C = \frac{Emf \text{ or } E}{R}$$

That the current is in direct proportion to the electromotive force admits of easy demonstration. If a circuit be used, containing a galvanometer, and a variable number of cells of equal electro-motive force, it will be found that as the number of active cells is increased the current will be increased proportionally:—If one cell gives one unit of current, two cells will give two units; ten will give ten units, and so on in proportion to the increase, providing the *resistance* to the current remains the same.

17. *Resistance* is that property in matter which restrains or blocks the current. It is the negation of conduction (§ 5); and the better the conductor, the less resistance. As conduction depends on the free and rhythmic vibration of molecules, so resistance depends on the rigidity or irregular vibration of molecules. It must be remembered that all ponderable molecules have a *vis inertia* which has to be overcome by the current, therefore even the best conductors offer some resistance.

Resistance is in direct proportion to the length of the conductor: This means that the greater the number of molecules in the direct path of the current—in enfilade—the greater the loss of force in overcoming the inertia.

All molecules have a natural gait of movement, which is hastened by the electric current, and this hastening is resisted by the molecules; an electric unit of potential has to overcome the resistance of those molecules in direct line between its starting point and the point of neutralization; and therefore the longer the line the greater the number of molecules, and the greater the resistance encountered.

Resistance is inversely proportional to the cross-sectional area of the conductor. As the current—the ether atoms—is traveling along its route by means of molecular vibration, the greater number of vibratory carriers there are *abreast*, the greater the amount of current, and the less acceleration of the normal vibratory speed, and therefore the less waste and resistance.

Resistance varies with the material of the conductor. Thus it is found that iron has six times the resistance of copper; this means that the molecules of copper vibrate six times faster than those of iron, and are capable of carrying six times the number of ether atoms past any given point, in a given definite period of time. The relative size of the molecule to its free or vibratory space, and its spherical balance in positivities and negativities, must modify the property of conduction.

The relative specific resistances of a number of metals at a temperature of 32° (F.) are as follows:

Silver	1	Iron	6.46
Copper	1.06	Platinum	11.3
Gold	1.38	Lead	13.50
Zinc	3.75	Mercury	62.50

The table shows that silver is the best conductor, and offers the least resistance to the current.

Liquids have comparatively very great resistances, as the following table shows:

Copper wire	at 32° (F.)	1
Sol. of Copper Sulph.	at 48° (F.)	16,885,520
" of Sodium Chloride	at 56° (F.)	2,903,538
Distilled water	at 59° (F.)	6,734,208,000

Resistance is affected by the temperature of the conductor. Pure metals have their resistance increased by raising their temperatures. Non-metallic substances have a lessened resistance by a rise of temperature. As the temperature of a metal is increased the intermolecular spaces are lengthened; this requires a longer swing of the molecule to bridge the space, and therefore gives an increased electric resistance. By raising the temperature of other substances the waves of heat bring their molecules more into line and tends to polarize them (§ 147), making them better carriers, and thus lessening resistance. Fixed molecular polarization makes the substance a non-conductor (§ 38).

Resistance is a relative property; the best conductors offer some resistance to the electric passage; and the best insulators allow some of the current to escape.

CHAPTER II

Ether

18. The subject of *Ether* may be conveniently considered under the following divisions:

1. Atomic Ether—Electricity.
2. Molecular Ether:
   - *a* Interstellar Ether;
   - *b* Intermolecular Ether—Ether between the molecules of ponderable matter.
3. Immolecular Ether—Constituent units of ponderable molecules.

The properties of ether-units are the fundamental bases of electric and chemic action. Electricity and chemistry are so intimately connected that the problems of the one cannot be solved without a solution of those of the other. Furthermore, when the two forces —chemic force and electricity—are reduced to their fundamental principles, these are found to be identical.

If the chemist could transport himself, without losing his analytical sense, to the border line between the sphere where ether alone exists and where matter begins to be condensed and influenced by the gravitation of the earth, he would find a whole world of new chemical elements. He could there examine at his leisure the "lost link" or links between hydrogen and ether.

Ether in its simple molecular construction of positive and negative atoms is the only existing thing that is self satisfied. The ether molecule is the only one

whose constituent forces neutralize each other. It neither attracts nor repels proximate molecules of ether. When we depart from the ether molecule and enter the sphere of ponderable matter, we find molecules of more complex character whose units are not entirely neutralized within, and whose forces therefore act outside of the molecular body. Regarding ether as the simplest form of matter, the first variation from this simplicity and complete immolecular neutralization of forces may be conceived to be represented in the following formulæ:

$\overset{+}{-}$	$\overset{+\ \ +}{-\,-}$	$\overset{-\ \ -}{+}$
A molecule of ether.	Positive primary condensation.	Negative primary condensation.

The formulæ represent molecules of ether, and the conceptions of the condensations of matter approximating ether in simplicity of construction. The latter may be named the positive and negative *elementary or primary condensations*. They represent positive and negative chemic molecules. Three ether molecules contain the same number of units as the two ponderable molecules. An analogous relationship exists between oxygen molecules and those of ozone. Further condensation may be effected by reactions between the multiples of elementary condensations, thus producing an incalculable variety of combinations. These are synthetic reactions, and require extrinsic force and pressure.

In dense matter there must be distortion of the form of the unit, but its impenetrability must be preserved. The tenuous condition of ether depends upon the minuteness of its molecular sphere, which consists of two units, and upon the immolecular neutralization of the forces of the ether molecule.

By multiplying the positive condensation accom-

panied by various synthetic reactions between positives and negatives, we arrive at the chemic atoms of the extreme positive elementary substances, such as the alkali metals. By multiplying the negative primary condensation accompanied by chemic reactions we will obtain, as a product, atoms of oxygen and of other negative elements. The combining of the two elementary condensations in various proportions, accompanied by additional condensation, and by chemic reactions, will account for the atoms and molecules of all intermediate chemically basic substances.

A primary condensation represents a unit of potential of positivity or a unit of potential of negativity, and is *equal in chemic potential to a free atom of positive or a free atom of negative ether, or a unit of electric potential.* Any multiple of the one combined with a multiple of the other will represent the molecule of a salt. Similar primary condensations form molecules which represent the molecular form of chemically elementary matter. This combination can only take place with complex matter, as similar elementary units or atoms cannot unite as a molecule, which is a body possessing the property of assuming differential poles (§ 26).

19. The friction produced by rubbing two pieces of wood together will produce sufficient heat to set the substance on fire, whilst the friction produced by rubbing silk on the surface of a metal will electrify both the silk and the metal. The explanation of this becomes clear on the basis of the negativities and positivities of different substances. If a substance that is made up largely of fundamental positivities is rubbed on a substance that is made up largely of negativities, the negative substance will attract the positive ether, and the positive substance will attract the negative

ether, and thus the two substances are electrified. If the two substances are not different in their fundamental positivity and negativity the friction merely sets free the ether molecule, without breaking it up, and the result is heat (§ 43, § 103).

All intermolecular spaces of ponderable molecules are filled with molecular ether. It is this ether that is ground out by friction either as heat or electricity (§ 43, § 67). Friction of two bodies disturbs the relationship of the intervening molecules in the air to their intermolecular ether. The ether is set free from the intermolecular polarized fields (§ 42) and radiates through the medium of the bodies rubbed. In the latter the intermolecular spaces are enlarged, whilst in the air the spaces are distorted (§ 23). A current of molecular ether—heat—is established from the rubbed surfaces through the bodies, and from their distal surfaces it is diffused. Or, the ether forms a charge on the rubbed surfaces.

When there exists in contact—such as in a solution—two substances of different chemic potentials, the molecules of the substances tend *to reform under lower potentials* with the evolution of heat or electricity. Whether heat or electricity is evolved depends on the relative positivity and negativity of surrounding media, just as in the case of friction (§ 3). Thus, dip a piece of zinc into a solution of sulphuric acid and heat is eliminated, but this heat can be converted into electric action by altering the relative conditions of positivity and negativity in the surrounding media (§ 43). The ether eliminated comes from the induced fields of molecules (§ 41, § 42).

It is found that an electrified body produces induced electrification or polarization of certain surrounding

bodies, the induced electrification being directly proportional to the primary electrification (§ 65—67). This is in accordance with a universal law that all forces have not only counter-forces, but also induced forces. Positive and negative electrifications are counter-forces, but both of these produce electrifications by induction which are manifested under certain conditions, but which exist under all conditions. A stone carried to the top of a hill has its counter-force in the fact of the atmosphere being placed nearer the center of gravity by the removal of the stone. Its analogous induced force is the pressure on the top of the hill. A positive chemic force, as that of the alkalies, has its counter-force in negative oxygen; and both of these have induced forces in *polarization of the intermolecular ether surrounding their individual molecules.*

Just as electrification produces electrification or polarization by induction, so the potential of a molecule, which is identical with electrification, acting on the proximate ether produces polarization of the ether's molecules. Electric and chemic potentials being fundamentally identical, we have only to study electric conditions to arrive at correct conclusions regarding molecular conditions. However, electric and chemic potentials differentiate in as much as the electric unit is entirely free, whilst the chemic unit is held fast in the constituency of the ponderable molecule.

In figure 4, A and B represent electrified bodies with induced magnetic fields. If C and D—electric conductors—are placed in the positions indicated they will become electrified by induction (§ 65, § 66, § 67). If C and D are then removed electrification immediately disappears from them; but the forces that induced the electrification remain, and must act upon something.

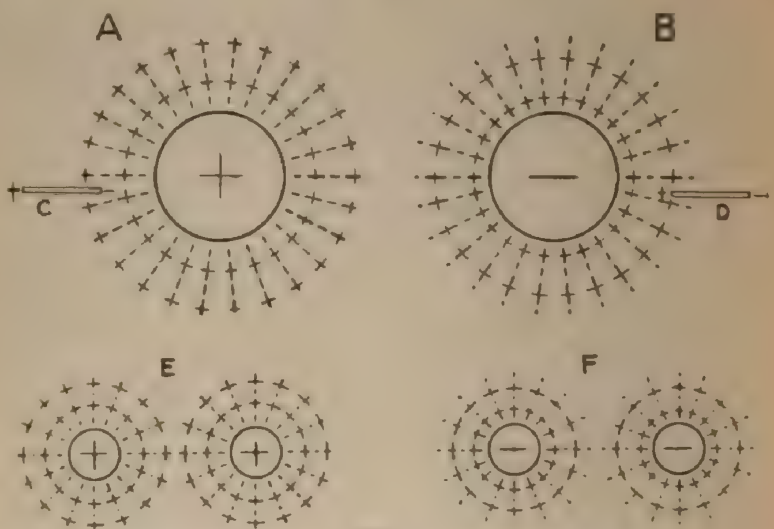

Fig 4.

Induced Polarization by electric and chemic Potentials: A and B, showing two bodies electrified positively and negatively with differentiated induced fields; C and D, conductors placed within the induced fields; E, two bodies electrified positively, or two electro-positive molecules; F, two bodies electrified negatively, or two electro-negative molecules.

As they acted upon the ponderable molecules and directly or indirectly on the intermolecular ether of the conductors, as manifested by the electrification, they will still act upon the ether that remains, the only difference being that there is no manifestation after the removal of the conductors C and D. In the electrification of A and B there is attraction between the bodies. E and F, being electrified similarly, produce electrification by induction as in A and B, with the difference that they repel each other (§ 23) by the impenetrability of their induced fields; and in the case of negative potentials there is an inherent repulsive property whose force is in inverse proportion to the square of distance (§ 28).

Molecules of ponderable matter possess potentials which must act inductively on the intermolecular ether,

and must attract or repel in like manner to electric potentials. If it be shown that the laws governing the electrification of bodies are identical with those governing the potential of molecules, it will follow that E and F will represent respectively electro-positive and electro-negative molecules of complex or ponderable matter.

20. *Interstellar Ether.* That "nature abhors a vacuum" is of universal application: All space is occupied by matter, at least as far as the spherical form of matter will permit of occupancy; as matter has extensibility, so space is occupied. This conception leads to the formularization of a law of occupancy or a law of tenuity or diffusibility as a counter law to that of gravitation. By the law of tenuity matter tends to diffuse, by gravitation matter tends to aggregate. In the ether condition tenuity has three factors: (1) The impenetrability of the ether molecule; (2) its spherical form; and (3) the *complete neutralization within the molecule of the inherent forces of its atoms.* In more complex matter tenuity has three factors: (1) The mutual repulsion between exmolecularly neutralized negative units forming the constituencies of molecules—inductive potentials of molecules; (2) the spherical forms of molecules with induced polarized fields; (3) the impenetrability of molecules, of their potentials, and of their induced forces.

In the denser forms of matter gravitation is the greater force. In ether the law of tenuity is supreme, and ether accordingly fills all space not occupied by denser matter. The forces of the ether molecule being immolecularly neutralized, it is not influenced by gravitation and it is imponderable.

Ponderable matter becomes more tenuous, and maintains an equilibrium in the space occupied, according

to the following law: *Molecules dissociate with increased molecular potentials and increased areas of the molecular induced fields, until the primary condensations are reached, which is the maximum of ponderable tenuity;* a free molecule of ether cannot become more tenuous (§ 138, § 139); and the limit of ether density is attained by polarization in an induced field.

21. *Intermolecular Ether* occupies space between molecules and is itself molecular in character. When a molecule is raised in potential the polarization of the intermolecular ether is increased (§ 42). This may occur with or without an increase of the number of atoms or units in the molecule; or molecules may be split up into a greater number of molecules with increased total potential and increased polarization of ether (§ 37). This process has been described as heat being absorbed or becoming latent, or energy changing from kinetic to potential. This is the case in all anabolic changes in animal and vegetable life, and in chemic actions when heat or electricity is converted into chemic potential.

During chemical processes, when the reactions take place between molecules without extrinsic force, molecular properties become more neutralized, and in the rearrangement the molecules are more evenly balanced in their positivities and negativities, thereby lessening their potentials, lessening their induced fields, and depolarizing part of the ether in these fields; consequently heat is evolved (§ 41, § 43).

Intermolecular ether forms a *physical equilibrium* with other matter. It is the medium of manifestation of heat and light and is also affected by sound. Intermolecular ether is *increased* within the mass when solids become liquid, or liquids become gaseous. Heat

is then said to become latent or to be absorbed by the physical change. When a gas is compressed the intermolecular spaces are diminished in size and the intermolecular ether is pressed out as heat, or as a flash of light if the compression be sudden. Most substances enlarge under the influence of heat, which means that ether is increased in the intermolecular spaces; as cooling takes place ether is evolved and heat radiated. Heat, however, may be absorbed without increase of bulk (§ 22). Certain solid substances have more intermolecular ether than others which are liquid. This is due to the quality of their molecular potentials (§ 36).

Intermolecular ether exists in two states, the polarized and the free. The polarized is in the induced fields of molecules. The free exists outside of these fields, and may represent the potential of diffusibility. The free may also exist as a thermic potential in the interspaces of molecules (§ 37).

22. *Properties of Molecular Ether.* Interstellar ether exists in the molecular form. The ether molecule has no potential, no inductive power, and no counter-force; it is composed of a single positive and a single negative atom, and the properties of the one atom are entirely neutralized by the properties of the other. As attraction and repulsion are entirely neutralized within the molecule, it has no cohesion, and the ether mass has absolutely no adhesive properties.

An ether mass offers no resistance to bodies passing through it, being incapable of friction as its forces are immolecularly neutralized. The ether atom is possessed of the properties of indestructibility and extensibility or impenetrability. The molecule has no fixity of position and requires no force to displace it to

the extent of non-interference with its impenetrability and globular form.

Ether cannot originate vibration, because it has no molecular potential. Having no potential it can give no sympathetic vibratory response. But by virtue of its extensibility and elasticity ether propagates vibrations or undulations. That is, it propagates vibration by contact. The cause of wave motions of the molecules of ponderable matter must be considered, and it will be found that these causes produce different effects on ether from those produced on other matter (§ 269, § 282). By its extensibility, elasticity, and by molecular polarization ether has the property of transmitting force.

In the free state the molecule of ether must assume the globular form, as the forces when inmolecularly neutralized must favor this form. As the form of the ether molecule is spherical, there must be intermolecular spaces notwithstanding the spheres are in contact, but a kind of matter that fills up all other pores must have interspaces that are very minute.

Ether is imponderable because its forces are *neutralized within its molecule;* its immolecular forces are only disturbed by greater forces which act in inverse proportion to the square of distance. As the positive and negative units of the ether molecule are in direct and maximum contact, being drawn together by their inherent properties, the factor of distance is at its minimum, which largely eliminates interferences by exmolecular forces. It is apparent that any two bodies in surface-contact have distances between individual portions of their masses as the contact-line is without breadth; so it is evident that ether-units although in contact must have distances between portions

of their neutralizing forces, and that although the ether molecule is exempt from external disturbing influences, such as gravitation, other forces with no neutralizing proximate potentials will disturb the intrinsic neutralization of the ether molecule in accordance with the law of distances. Thus it is evident that ether filling intermolecular spaces will be polarized by molecular potentials according to the same law by which interstellar ether is imponderable. It is also clear that in accordance with the law of forces the ether molecule may be dissociated by other potentials.

By maximum contact is meant the greatest relative area of surface-contact between quantities of matter qualitatively opposed—it is that condition where there is minimum distance between neutralizing forces. It is obvious that as all matter is molecular, and as all molecules have differential polarity, that the ether condition is absolute zero potential. It may be contended that however minute ether molecules may be, there will be a certain amount of cohesion between the positive unit of one and the negative unit of an adjoining molecule. This would be the case if the ether molecule were larger than the equilibrium of matter and force in relation to space demanded. Owing to this equilibrium ether molecules of larger size would immediately divide by polar attraction and equilibrate as smaller bodies. A larger ether molecule than the normal is an impossibility. In ponderable matter there are molecules which mutually attract and others which mutually repel, and the ether molecule is the equilibrated medium where attraction and repulsion are balanced.

An ether mass is mechanically incompressible not because of any inherent property that makes it incompressible, but because of there being absolutely no

means of impounding it—there is no solid through which it will not pass. The ether molecule can be distorted from the spherical to the cuboid form by polarization, and in this manner the ether mass is compressed. The polarization of ether is accomplished by the attractions and repulsions of exmolecular forces according to the law of forces as above stated. Under polarization ether molecules assume closer relationship. They depart from their spherical form, and consequently there are a larger number of ether molecules within a given space than in the free or depolarized condition. Thus heat applied to a gas which is prevented from expanding will in part become latent. The molecules of the gas are broken up into atoms or groups of atoms by the heat—a stream of ether molecules—and these atoms have an increased total potential, in fact they become molecules or submolecules and are surrounded by polarized fields. According to the degree of additional potential so additional ether is polarized and heat-energy is stored. Thus when a quantity of oxygen gas is confined so that it cannot expand, and its temperature is raised, a certain quantity of heat will become latent. The molecules of oxygen are prevented from separating, but the oxygen atoms, or definite groups of immolecular units potentially proportional to the degree of temperature, are dissociated. Hence each atom assumes the molecular condition (§ 37) with increased potential, increased polarization of ether, and consequently more ether within the induced fields of the molecules.

The ether molecule is elastic, the elasticity depending on its normal globular shape. When struck by a vibratory blow the ether molecule is capable of modifying its form, but by the attraction of its atoms it

immediately assumes the globular form when the compression is withdrawn.

Ether is not a conductor of electricity, because the attractions and repulsions within its molecule are fully satisfied, and the free atoms of ether—electricity—do not adhere to the surface of the ether molecule (§ 5, § 7). At least they do not adhere to ether in the presence of other matter.

In consequence of ether being imponderable it cannot be projected as a real ray of energy, as in the case of a cannon ball. Ether, however, by its attractions and repulsions may form vortices when in the induced field of an electric current (Fig. 18). Here the positive ether circulates in one direction and the negative in the opposite (§ 105).

23. *Differential Properties of Ether Units.* Attraction and repulsion are fundamental properties of ether atoms (§ 4). There is, however, as shown by the behavior of positive and negative currents, and positive and negative chemic elements, a fundamental difference in the character of units not explainable by the law of attraction and repulsion as *previously* formulated. The difference of the inherent properties of the positive and negative ether may be characterized as a diffusibility amongst negative, and a concentrativeness amongst positive atoms. The differential action of the currents on the blood (§ 164), the variation of the spark in using different sizes of electrodes at the positive and negative poles (§ 95), the fact of negative chemic elementary substances inclining towards the gaseous state, and positive elementary substances towards the solid (§ 36), thus making the solid mass of the earth preponderatingly positive, and the atmosphere negative; and other phenomenal facts, point to a fundamental dif-

ference in the character of the ether atoms as representing unit-matter. The important fact that their union is complete neutralization or zero confirms the differentiation.

As all natural phenomena depend upon the elementary properties of ether-units, it is important that these properties should be defined correctly. The

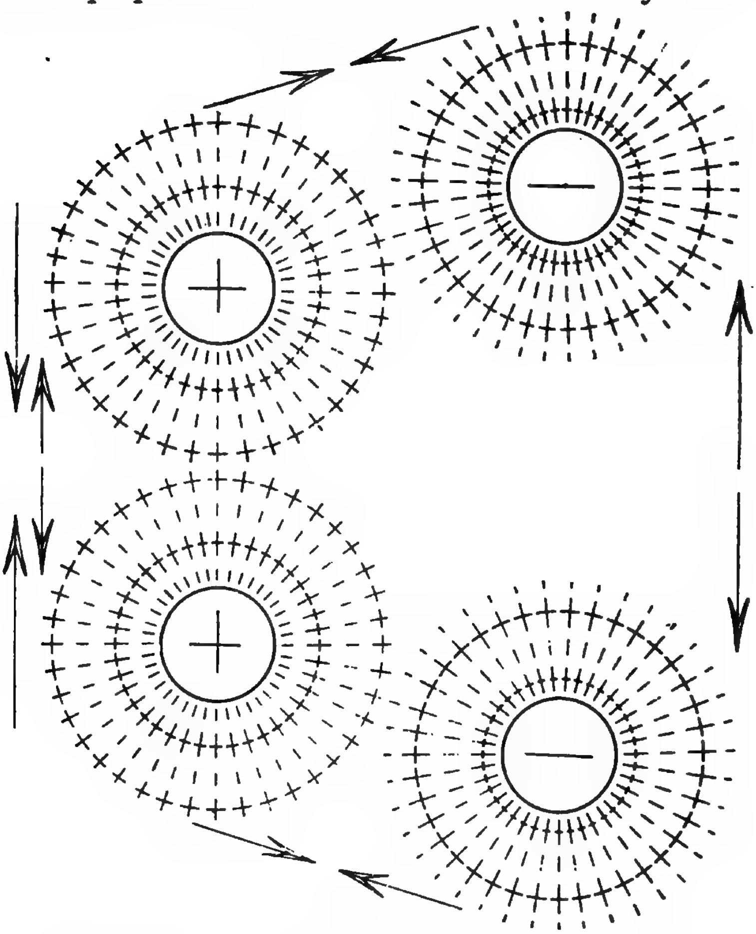

Fig. 5.
Representations of Attraction and Repulsion of Ether-units as manifested in Electrifications.

author believes that the differential properties of the units are expressed in the diagram, Fig. 5.

Matter has the property of impenetrability and the forces of matter are equally impenetrable; moreover, induced forces are impenetrable; hence like potentials will repel each other to the extent of their induced fields. This form of repulsion depends on the impenetrability of induced forces and not on an inherent repulsive principle.

The concentrativeness of positive ether shows that positively charged bodies will attract each other by inherent attraction. The attraction, however, will be resisted to the extent of induced areas by the impenetrability of induced forces.

Negatively charged bodies have impenetrable induced fields, and the diffusibility of the negative current shows that there exists an inherent repulsive force in negative ether atoms. Negatively charged bodies will therefore repel each other by induced impenetrability to the extent of their polarized areas; and they will repel each other by inherent repulsion directly proportional to the product of the quantities of force, and inversely proportional to the square of distance. The differential manifestations of a given potential evidently will be in inverse proportion to each other. Thus inductive neutralization is inversely proportional to primary neutralization. Thus it will be seen that there is a unit of ether representing a unit principle of attraction, or a unit of positivity; and a unit of ether representing a unit principle of repulsion, or a unit of negativity. The differential characters of units are clearly manifested in the property of cohesion in positive elementary substances

such as the metals, and in the absence of cohesion in negative elementary substances such as oxygen.

The conception is clear that a unit of attraction will attract a similar unit, and that similar units of repulsion will repel mutually. It is more difficult to conceive why a unit of repulsion is attracted by a unit of attraction; however, it is manifest that upon union of positives and negatives depends the equilibrium of matter and force in their relation to space. Union of positivities is a *union without uniform shape;* union between positivities and negativities results in *spherical forms* having common polar characteristics, and common properties, differentiating only in quantitative and qualitative potentials. A unit of negativity being repelled by similar units will seek union with units of positivity where there is attraction. The fundamental law of attraction and repulsion is formulated as follows: *Units of attraction (positivities) mutually attract; units of repulsion (negativities) mutually repel; and units of attraction and repulsion are attracted, mutually neutralized, and in maximum-contact are at zero potential.* This law, however, is subject to the equilibrium of matter and force in relation to space; and the first factor of the law (units of attraction mutually attract) is modified by the impenetrability of induced fields of positive potentials.

Elementary forces are classfied as follows (Fig. 4):

1. Attraction between positives—inherent concentrativeness.

2. Repulsion between negatives—inherent diffusibility.

3. Attraction between positives and negatives—the principle of equilibrium.

Induced potentials by the property of impenetra-

bility oppose attraction between positives, and assist repulsion between negatives. Attraction between positives and negatives may result in neutralization of primary potentials thus causing the disappearance of induced potentials

24. The finite cannot comprehend the infinite. However, the finite can take a representative part of the infinite, and examine the laws and conditions pertaining thereto which then can be applied to the infinite. If in a given definite space there is a given quantity of matter, which when in the solid, liquid or gaseous state, is not sufficiently large to fill the space, but which in the tenuous or ether state is too large to occupy the space, then the matter must be adjusted in the several states of aggregation and tenuity so that its bulk corresponds with the dimensions of the space. It is evident that any change in the state of matter taking place in one part of the space will produce an opposite change in another part (§ 205). We have only to make the space and matter infinite in dimensions and quantity to form a conception of the transmutations that are occurring in the various states of matter in the universe. Natural processes therefore consist of reciprocal phenomena. For instance, if an atom of hydrogen on the surface of the earth were reduced to ether, concurrently, somewhere in space, under proper conditions of pressure, the proper quantity of ether would be condensed to a hydrogen atom, or condensation of equivalent potential would take place.

25. *Relation of Ether to Force.* Ether is not force, but all potential forces have corresponding ether conditions, and all kinetic forces produce ether changes (§ 14, § 41). Ether is the medium through which force is transformed. Thus chemic potential is changed into

heat or electricity, not by a change in the character of chemic atoms, but by lessening the induced polarization of ether in the molecular fields by a partial neutralization of the potential of molecules by chemic rearrangement, or by lessening the amount of free ether in the interspaces (Fig. 5). It is this ether whose potential of polarization, or potential of placement, manifests itself in another direction, and which is then known as another force. A potential is relative, it being more or less according to the standard of zero. When measured by the standard of an ether molecule all ponderable molecules have potentials. The equilibrium existing between the different kinds of matter is zero, and is a standard that varies in different conditions and at different places. The ether has a potential when its atoms are separated as in an electric charge, or when polarized in an induced field of a chemic or electric potential. Owing to its units being in maximum-contact, with minimum-distance between neutralizing portions, the free ether molecule has no potential, although it may be acted upon by potentials according to the law of forces. As all forces are neutralized, it is evident that *distance is the essentiality of potential.*

26. *Immolecular Ether-Units.* Physical, chemic and electric potentials are identical forces, having the same ultimate units—the properties of ether-atoms. It is true that electrification is simple, and physical and chemic energies are complex, but the fundamental laws of each are those of repulsion and attraction. If, then, they are identical forces, being governed by the same laws, having the same unit forces, it is evident that a study of the phenomena of the one will give us a

knowledge of the fundamental laws of the complicated phenomena of the others.

Immolecular ether-units give character to the multiplicity of the affinities of molecules and chemic atoms, the affinities depending on the relative number of positive and negative units in the construction of a molecule or atom. Chemic atoms, being representations of positive and negative units, are thus capable of combining to form molecules of chemically elementary matter, a fact which is impossible in the case of similar units of ultimate matter—ether. Thus two hydrogen atoms unite to form a molecule, and two oxygen atoms unite in like manner. Immolecular units characterize the vibration of molecules; thus metallic oxides have about equal positivities and negativities in their molecular construction and their molecules vibrate slightly and are poor conductors; on the contrary, the pure metals, having a large majority of similar units, vibrate freely and are good conductors.

The *molecule* is the physical unit. It is composed of constituents of positive and negative units identical with ether-units, which, by relative numerical proportions, by absolute numbers, and by relative placement, present distinctive molecular qualities of incalculable variety. The molecule when not distorted by extraneous forces assumes the globular form. It has the property of assuming differential poles. The potential of the molecule is represented by induction in a polarized field which surrounds the molecular body (§ 19). The tridimensional space within the circumference of the induced field is the free or vibratory space of the molecule. There are no free spaces within the molecular construction.

The molecule of ether consists of two units, has no

potential and no induced field; the molecule of ponderable matter varies in number of units from three in the elementary condensations to millions, perhaps trillions, of units in the complex organic molecule. The potential of a complex molecule is quantitative and qualitative, depending on the number, quality and relative placement of units in its construction.

Within the molecular construction there are groups of units which under the influence of polar attractions of other molecules dissociate. These groups of units have been called chemic atoms. As bodies, these groups have no distinct entities within molecules, and have no induced polarized fields. When a molecule is dissociated by heat or decrease of pressure it breaks up into smaller molecules of definite potentials and induced fields. These submolecules may be identical with the groups of units named chemic atoms. The chemic atom preserves its unity by virtue of the relative placement of the units in its construction and by the relative position that the atom or group of units occupies in the molecular construction, the immolecular attractions and the exmolecular attractions of an adjoining molecule being governed by the law of forces (§ 27). A chemic atom therefore maintains its chemic unity under ordinary variations of pressure and temperature. However, there is no doubt but there are degrees of tenuity in which the chemic atom is dissociated into smaller groups of units.

27. In a complex molecule, as shown by the property of differentiating its poles, there are distances between the majority of the positivities and the majority of the negativities which are important factors in the neutralization of the forces of the molecule; it is only in an

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chemic atoms within the molecule may be less than the standard of equilibrium.

6. *Immolecular Neutralization.* The number of positive and negative units that neutralize each other within the molecule, and are not disturbed by exmolecular forces, is embraced under this term.

The potential of the molecule may be attracted by the potentials of neighboring molecules, as manifested in osmosis or diffusion, these being forms of polar or inductive attraction without chemic action.

Polar potentials may be attracted and the molecules fixed by other polar potentials without any chemic dissociation as manifested by the properties of cohesion, rigidity, etc. Cohesion has two forms: Attraction between polar potentials of different quality, as in gutta-percha, glass, etc.; and attraction between positive potentials, as in water, metals, etc.

It is obvious that neutralization by exmolecular forces will not represent the total number of units in the molecular construction. The immolecular forces under all conditions will to some extent be self-neutralizing, and this immolecular neutralization is not measured by extrinsic forces. This form of neutralization may be a factor in differentiating the weight of elements in relation to bulk.

28. *Gravity Potential or Gravitation.* The law of gravitation has been defined as follows: "Every particle of matter in the universe attracts every other particle with a force whose magnitude is directly as the product of their masses, and inversely as the square of their distance from each other." This is incorrect. All bodies do not attract each other, two molecules or masses of oxygen do not attract each other (§ 33); and the author believes that no two electro-negatives mu-

tually attract, although they may approach each other by being attracted towards a common center by another potential. The definition eliminates repulsion from being an inherent property of matter and leaves attraction as the only fundamental principle. If the law were correct as stated, gravitation would act on all matter quantitatively and qualitatively alike; but it is plain that solids must be preponderatingly electropositive as the elements of the atmosphere are electronegative. Furthermore, attraction between bodies is modified by the character of media. Newton framed his law in reference to planets whose medium is constant, but intraplanetary bodies have changeable media.

Obviously there are in existence an equal number of positive and negative units of matter. In the simple form of matter—ether—this equilibrium is preserved throughout space. In the more complex form, taking the states individually, this equilibrium does not exist, the atmosphere being almost wholly composed of electro negatives. Hydrogen is the only common chemical element which is electro-positive and gaseous in character, and its quantitatively minute molecule is significant of a universal principle. Electro-positive molecules quantitatively as large as the oxygen molecule are solid, as, for instance, carbon, which is less positive than hydrogen, and less in atomic weight than oxygen. These facts are not consistent with the above definition of gravitation, and they prove that gravitation—attraction—does not universally affect matter alike.

If gravitation acted on all matter alike, condensation of the electro-negative units would take place simultaneously with electro-positives. It is apparent that the principle of concentrativeness inherent in positive

units is an important factor in the attraction between masses.

In formulating ultimate laws of force the following factors have to be considered: (1) The inherent concentrativeness—attraction—of positive units; (2) the inherent diffusibility—repulsion—of negative units; and (3) the attraction between the positive and negative units.

1. The property of concentrativeness inherent in the positive ether atoms accounts for some unexplained phenomena which in a general way are embraced under the term gravitation. It explains why the masses of solids are composed largely of electro-positive elements, a fact which gravitation as at present formulated does not.

Positive concentrativeness modifies the law of unlikes attracting and likes repelling. There can be no repulsive principle inherent in positive units if the inherent property is concentrativeness; but the facts that heretofore have been explained by positive repelling positive can be fully explained by unlikes attracting, as where there are free positive units there are also somewhere in the environment free negative units, so that, when two positively charged bodies separate, they do so by the attraction existing between the negative and the positive charges on proximate bodies; moreover, mutual repulsion of positively charged bodies or of positive molecules is caused by the *impenetrability of the induced fields* of positive potentials.

2. The diffusibility of negative units tends to make all the electro-negative elements diffuse throughout space. It is the most important factor in maintaining gaseous conditions. It is owing to this property

that the atmosphere is almost exclusively composed of electro-negatives such as oxygen and nitrogen. It accounts for the fact that the molecules of these elements are gases although comparatively quantitatively large. Owing to the diffusibility of electro-negatives, and the concentrativeness of electro-positives, the gaseous elements in a Crookes tube consist of comparatively large negativities and comparatively small positivities (§ 143), and these facts illustrate a uniform principle, as shown by the relative size of oxygen and hydrogen molecules.

Negative diffusibility fundamentally must be an active repulsive force, which is demonstrated by the remarkable phenomenon of the cathode rays in a Crookes tube proceeding in straight lines independently of the position of the anode. This fact, isolated in character, can be explained on no other hypothesis than on that of there being an inherent principle of repulsion in negative ether atoms (§ 23).

3. It is clear that the principle of concentrativeness in positivities and of diffusibility in negativities tend to separate matter into two grand divisions. This catastrophe is prevented by the principle of attraction existing between the positive and negative units. The principle embraces chemic affinity, and is also a factor in the production of the phenomenon of diffusion of gases and liquids. The principle therefore is manifested without chemic disturbance taking place. Whether the principle of attraction as existing between positives and negatives resides entirely in positive elements, or whether it belongs to positivities and negativities, is perhaps practically insolvable. It is reasonable to conclude that a positive unit represents, and represents only, a unit principle

of attraction, and it is inconceivable that the principle of repulsion could be represented with its opposite in the same ultimate unit. When a positively charged body moves towards a negatively charged body, it is because the negative is so fixed that it cannot move, or requires relatively more force to move towards the positive. The latter will move by its own inherent attraction towards the former. Attraction existing between positives and negatives must be greater than that between two positives as represented by the concentrativeness of the latter, as positives will leave other positives and unite with negatives. Further, the repulsive principle inherent in negativities by mutual repulsion assists the union of negativities and positivities. Hence the sphere of action of the fundamental principle attraction embraces negativities; but the attraction between positives and negatives depends on factors that maintain an equilibrium of the different states of matter (§24, § 21) and their forces in relation to space. This form of attraction is the equilibration of opposites which seek zero-potential.

29. Primary elementary forces, as manifested in positive and negative molecules of gases, are diagrammatically illustrated in the accompanying figure.

Fig. 6, shows positive molecules as having small ponderable masses—the inner circles—large inductive potentials and large induced areas—the outer circles—and these in contact with slight distortion; and negative gases as having large molecular ponderable masses, small inductive potentials, and small induced areas with slight distortion. The tridimensional space, occupied by the ponderable molecule, the induced field and interspace, is dimensionally equal in all molecules

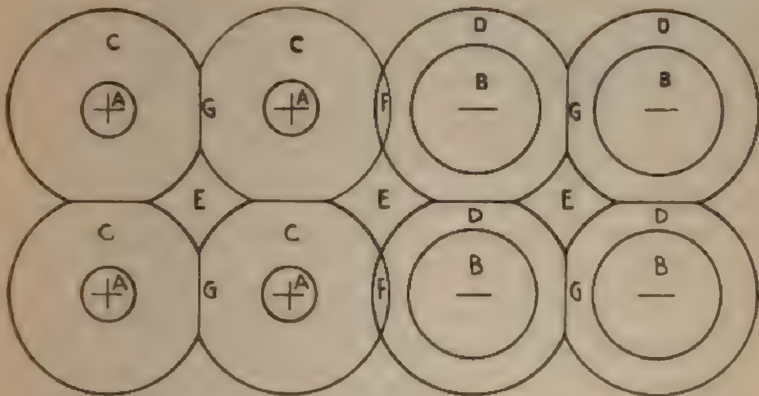

Fig. 6.

Representations of electro-negative and electro-positive molecules of gases: A, positive ponderable molecule; B, negative ponderable molecule; C, D, induced fields of positive and negative molecules; E, free interspaces; F, overlapping of positive and negative induced fields; G, distortion of fields showing impenetrability of similar potentials. Their spacial occupancies are equal in dimensions.

of gases under like conditions of pressure and temperature (Avogadro's law), and may be termed the *molecular space*.

The deduction has been made (§ 23), (Fig. 5) that positive bodies repel each other, but they repel only to the extent of their induced fields. When the induced fields of positivities are considered as parts of the molecules or electrically charged bodies, there can be no repulsion between them; on the contrary, there is attraction as manifested by cohesion of positive molecules. The mutual repulsion of positivities to the extent of their induced fields is not repulsion in principle but rests on the impenetrability of force, *i. e.*, a positive potential occupying an induced magnetic field prohibits the occupation of the field by another potential of the same character (Fig. 5). The field can be distorted, or the potetential can be neutralized by a

potential of opposite character, but it is impenetrable to a like force. *The distortion must vary directly as the molecular weights, supported by positive inductive potentials, and opposed by negative inductive potentials.* The electric or magnetic analogue of molecular distortion is indicated in Fig. 37, B.

The negative induced fields are also impenetrable, and the inherent repulsion of negative units mutually react inversely proportional to the square of distance. In the induced fields the ether is polarized; in the spaces between the induced fields (in gases) there is depolarized or free molecular ether where there is little or no distortion. These are named *molecular interspaces.* Between the induced fields of positive molecules of medium or great molecular weight there is little or no interspace, as the inherent principle of these molecules is attraction, consequently these are solids or liquids. Between the induced fields of negative molecules of large molecular weights there is little or no interspace, because the molecular weights approximate the molecules, thus distorting the fields and lessening or eliminating the interspace, consequently negatives of large molecular weights are solids or liquids. Between positive and negative molecules the induced fields overlap, there being more or less neutralization of the induced force. If the attraction between the positive and negative is sufficiently strong, chemic reaction takes place. The attraction and partial neutralization of induced forces without chemic reaction between the primary potentials explains the phenomena of solubility, diffusion and osmosis.

Hydrogen unites with oxygen and other negatives because of opposite quality, with increased immolecular neutralization, decreased molecular potential, decreased

area of the induced fields, and accompanied with the emission of heat. Hydrogen unites with carbon with increased molecular weight, thus distorting the induced fields and eliminating ether from the interspaces; when united there are polar attractions, but the differential induced areas (distortion) are the important factors in the union; in organic matter they often act as one atom, a radical. Hydrogen has no affinity for the heavier metals because of similar quality, and because the heavier elements have their molecular fields distorted to the fullest extent. Negatives unite with negatives with increased distortion of the induced fields, resulting from the increased molecular weights, and with the evolution of heat, even oxygen burning in its own atmosphere (§ 203) but requiring extrinsic initiatory force. The induced fields of positive and negative molecules are directly proportional to their inductive potentials, but, there being attraction between positives and repulsion between negatives, it is clear that fields will differ as to the degree of distortion for equal potentials of different qualities, under like conditions of pressure and temperature. As the degree of distortion is an important factor in determining the physical state of matter, it is evident that the molecular quality (positive or negative) of matter by increasing or diminishing the distortion is also a factor. Density depends not only on distortion of the constituent units of the ponderable molecule, but also upon distortion of the molecular induced field, and the latter may take place to the extent of eliminating the free interspace. It is obvious that as in positive molecules the other factors of distortion are assisted by the attraction of the molecular potentials, and that as in negatives the other factors of distortion

are opposed by repulsion of molecular potentials, there are differentiated degrees of distortion and differentiated interspaces, and consequently differentiated degrees of density in matter, depending upon the positive or negative quality of molecules. Furthermore, as gravitating potential varies with density, it is conclusive that the positivity or negativity of the molecular potential will determine the degree of gravitating potential. Clearly positive molecules have a tendency towards solid, and negative molecules toward gaseous conditions.

Gravitation, however, is not always proportional to density. It is conceivable that within the molecule there are different relative placements of the units whereby immolecular neutralization varies, and it is evident that forces neutralized within the molecule cannot be measured by extrinsic potentials. A very light metal may have more units in its molecule than a very heavy one; aluminum may have more immolecular units than iron, the difference being in the relative placements, whereby surface-contact of neutralizing units, and the relative amounts of intrinsic and extrinsic neutralization vary. Obviously there is distortion of the unit from a hemispherical form as in the ether molecule to a variety of forms in the ponderable molecule, and there is distortion of the induced field in proportional degrees (Fig. 6). Consequently density is directly proportional to distortion, and it follows that distortion being more in positives than in negatives, owing to their inherent properties of attraction and repulsion, that positives will incline to density and negatives to rarefaction. Putting aside the factor of immolecular neutralization, gravitation is in direct proportion to density, and consequently acts on positives more than on negatives. The principle of distortion

differentiating in positive and negative elements explains why only relatively small positive molecules assume the gaseous state. However, in the primordial arrangement of units it is evident that the inherent attraction of positives would lead to concentrativeness as in solids, and the inherent repulsion of negatives would lead to diffusibility as in gases, independently of the distortion and density which follow the molecular condition.

Changes in molecular potentials will affect the intermolecular ether as follows:

1. Reactions between positives and negatives increase immolecular neutralization, decrease the ether in polarized fields, producing ether-radiation.

2. Reactions between negatives add to molecular weights, increase distortion of induced fields, ether radiating from free interspaces.

3. Reactions between positives add to molecular weights, increase distortion of induced fields, ether radiating from free interspaces.

4. Changes from solids to liquids, and from liquids to gases, lessen the distortion of the induced fields and increase the ether in the free interspaces.

5. Changes from gaseous state to liquid, and from liquid to solid, increase distortion of induced fields, with ether-radiation from free interspaces.

6. Decrement of pressure or increase of temperature produces effects in the following order: Increased dimensions of the interspaces; dissociation of molecules or rearrangement of atoms, with increased molecular potentials and increased dimensions of induced fields. These changes are accompanied with absorption of ether.

7. The changes may be more or less associated,

and may support or annul each other in their effects. The effects also may be modified by the interspaces being previously encroached upon by distorted induced fields.

30. Gravitation has been defined as a gravity potential, and as the sum of the positive and negative units of the molecule attracted by the positive inductive potential of the earth, divided by the sum of the units neutralized within the *molecular space.* It is evident that units immolecularly neutralized, or neutralized within the molecular space, and without weight, have an equilibrated position outside of the earth's sphere (except where they fill the interspaces of equilibrated ponderable matter). Hence molecular ponderable units are in a position as if placed in a vacuum—the molecular space—which, when of sufficient dimensions, will carry them upwards. Each ponderable molecule is like a weight inside of a balloon. The specific gravity of matter depends on the relativity of its *molecular quotient.* The following law governs attraction and repulsion: *Forces react in inverse proportion to the square of their distance asunder.* Gravitation has two factors: (1) The concentrativeness or mutual attraction of positive ether-units; and (2) the attraction between positive and negative units, or the force of equilibration.

Within a molecule are placed a number of positive and negative units. As the molecule is a sphere with the property of polar differentiations (§ 26), there are distances between the majority of the positivities and the majority of the negativities which are factors in determining which force takes possession of the immolecular units. Whether the forces of the earth neutralize these units, or whether they are neutralized

within the molecule, is determined according to the law of the reaction of forces as above stated. The positivities of the molecule and the positivities of the earth are mutually attracted by inherent concentrativeness, and the negativities of the molecule are attracted by the positivities of the earth, but these attractions are always governed by the law as above defined.

In a free ether molecule the atoms are in maximum-contact with minimum-distance, hence their properties are completely neutralized within the molecule, and distance is largely eliminated as a factor in the law of forces. In a complex molecule neutralization of units is incomplete because each individual unit is not in maximum-contact with one of opposite quality. It is estimated that the molecule of hydrogen contains six thousand units, and it has differential poles, and as attraction between bodies is inversely as the square of their distance, it is impossible for complete immolecular neutralization to take place in the presence of the forces of the earth. If oxygen is added to hydrogen, part of their forces are mutually neutralized, but immolecular distances prevent complete neutralization, therefore the forces of both are largely under the influence of the immense positivity of the earth. Hence the relatively immense and incompletely neutralized forces of the earth attract all incompletely neutralized forces within a lesser body, or within a molecule, and the *standard of the conditions under which complete immolecular neutralization takes place are those of an ether molecule.* A complex molecule of matter with an equal number of positive and negative units in its construction would neutralize its own forces if apart from the larger mass of the earth; but when within the earth's sphere the forces of the larger mass

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take possession of the incompletely neutralized positivities and negativities of the smaller body. Hence a meteor is chiefly attracted toward the earth: (1) by the positive attraction between the meteor and the positivities of the earth, and (2) by mutual attraction between the positivities of the one and the negativities of the other. An electro-negative meteor is an impossibility, and even if found it could only reach the atmospheric circumference where it would be diffused in a similar manner to a residual gas in a Crookes tube. These bodies might have an electro-negative atmosphere before reaching the sphere of the earth. The relativity of its molecular quotient is an important factor in the descent of the meteor.

Molecular weight is relative gravitating attraction, the molecular weight of hydrogen being the unit. In considering the relative weight of substances the molecular space must be regarded as part of the molecule. Thus the molecular weight of hydrogen depends upon the number of ponderable units within its molecular space, but the ether in the induced field and interspace, and the intrinsically neutralized force within the ponderable molecule, have no weight. Exmolecular neutralization, divided by immolecular neutralization or neutralization within the molecular space, gives a quotient of molecular weight.

31. *Polar or Chemic Potential.* Chemic action is polar in character. Chemic potential is the amount of exmolecularly neutralizable positivities or negativities concentrated at a pole of the molecule. Chemic reactions are the result of attraction between positive and negative units at the opposing poles of adjoining molecules. Valency is thus explained. The intensity of action is relatively independent of gravitation or atomic

weight, but the attraction is the same in kind to the extent that gravitation depends on the attraction between positives and negatives.

Molecular weight is directly proportional to the sum of exmolecularly neutralized units (positivities and negativities, chemic potential is the amount of force concentrable at a molecular pole, and its intensity depends upon the difference between the sum of the molecular positivities and the sum of the negativities. However, a molecule having equal positivities and negativities may have its unit forces concentrated at its poles by an equal or greater potential of another molecule. This class of molecules has weak chemic action which is passive in character, therefore chemic polarities are divided into *active* and *passive* potentials. Polar action takes place according to the law of forces. It is also influenced by the tendency towards an establishment of a physical equilibrium of matter in relation to space.

32. *Inductive Potential.* Inductive potential corresponds with active chemic potential. It is represented in the induced field and polarizes the ether within the field. When part of the inductive potential is neutralized by chemic action a corresponding part of the polarized ether of the induced field is set free and radiates as heat or becomes an electric potential or current (§ 42). Ether is polarized in the field because it is the only element so molecularly minute as to enter the intermolecular spaces, and its polarization accords with the law of forces.

33. *Potential of Concentrativeness, and Potential of Diffusibility.* All forces tend towards an equilibrium. This does not imply that force tends to bring all matter to the same physical state, but to adjust the states of

matter so that the elementary forces are balanced in space. The equilibrium is different for different kinds of matter according to the number and kind of ether units in its molecular construction. A potential based on an equilibrium of matter varies according to its incidental environment.

The potentials of concentrativeness and the potential of diffusibility have the following forms: (1) Molecules may vary from the equilibrium in the number of units in their construction—increased number or potential of concentrativeness; decreased number or potential of diffusibility. (2) The interspaces may vary in dimensions—decreased area or potential of concentrativeness; increased area or potential of diffusibility.

Extrinsic forces producing modifications of pressure or temperature are transformed into these varieties of the potentials of concentrativeness and diffusibility. Thus molecules of residual gas in a vacuum tube become submolecules, or smaller molecules, which are in equilibrium; as soon as the air is allowed to enter the tube the submolecules have a potential of tenuity. Molecules built up to an equilibrium under certain conditions of temperature and pressure have a potential of concentrativeness under other conditions; for instance, molecules of glucose are in equilibrium in the plant, but when in the circulation of the animal organism they have a potential. Oxygen molecules have inductive potential and a potential of diffusibility (Figs. 5, 6). If a mass of oxygen is compressed to a liquid there is a potential of concentrativeness. The intermolecular spaces have been encroached upon and the ether of the interspaces has been forced out by the distortion of the induced fields. When the compression is withdrawn the outer molecules of the liquid fly off, and this

process is continued until the oxygen regains its equilibrium. To the inherent force of repulsion, and to the elasticity of the induced fields, is mainly due the property of oxygen of regaining the gaseous state. Matter has distinctive molecular characters based upon the quantity, quality, and relative placement of immolecular units, and this distinctiveness determines the specific magnitude of its molecules and their physical state in the equilibrium of matter in relation to space, and is a factor in the expansion of all gases, whether positive or negative, when the force of compression is removed. The following formulæ will show how potentials of diffusibility are transformed:

$S + O_2 = S\,O_2 +$ Heat—ether from interspaces of oxygen.

$H_2 + O = H_2\,O +$ Heat—ether from interspaces and induced fields of both elements.

$C_2 + (H_2)_4 = (C\,H_4)_2 +$ Heat—ether from interspaces of hydrogen.

Sulphur and oxygen are negative, their chemic union therefore will not alter their inductive potentials. Sulphur has a potential of diffusibility, but it is neutralized by its molecular weight (§ 29). Oxygen has a potential of diffusibility which is represented by depolarized or free molecular ether in the interspaces (Fig. 6). By adding a sulphur atom to the oxygen molecule the potential of diffusibility of oxygen is partly neutralized by the atomic weight of sulphur and the free ether of the interspace is pressed out by the increased molecular weight distorting the induced fields. The size of the ponderable molecule is increased, the induced field is increased, but the amount of ether in the interspace is diminished, hence the heat.

There are many instances of positive elements uniting with positives accompanied by the production of heat, the reactions being analogous to those of sulphur and oxygen modified by the greater distortion of the induced fields, and encroachment on the interspaces, by positive attraction re-enforcing the molecular weight. *Consequently positive elements require greater extrinsic dissociating force.* Thus the "heat of mixtures" of positive elements such as zinc and copper is evidence of a readjustment of the molecular interspaces with the elimination of ether. The many chemic combinations of carbon and hydrogen, although requiring an initiatory dissociating force, must be accompanied by the evolution of heat—ether from the molecular interspaces of hydrogen. Thus carbon set free in molecular proportions from an electric pole, placed in an atmosphere of hydrogen, will form acetylene gas C_2H_2, and the union must set free ether as heat, although the heat of formation is given as — 48300. heat units.

The chemic union of hydrogen and oxygen results in decreased inductive potential and decreased potential of diffusibility on the part of both elements, and consequently a large quantity of heat is eliminated—ether from the induced fields of both elements, and free ether from the interspaces of both.

34. It is conceivable that under certain conditions of pressure or temperature ordinary chemic atoms or definite integrant parts of molecules may become molecules; and conversely, molecules may become parts of larger molecules. In this respect the relation existing between atoms and molecules may be defined as follows: An atom is that part of a molecule which is dissociated by chemic action; it is a constituent group of units forming part of a molecule and held together

in absolute contact with, and by attraction between it and the other constituents, the individual constituent groups having no induced environment. However, arrangement of units within a chemic atom is distinctive and is not disturbed by inmolecular attractions. On the other hand, a molecule is a physically distinct body, separated from other bodies by an induced field which is commensurate with its inductive potential.

Under increased pressure two molecules may become one, or a number may combine and form a less number, and under decreased pressure a molecule may be divided into two or more parts, each part assuming the molecular condition. Thus an ordinary molecule placed in the Crookes tube may be split up into thousands of molecules each composed of constituent units, and each surrounded by a distinct induced field of definite tridimensional proportions. Moreover, it is conceivable that by pressure, by polar attractions, or by the absence of inductive potential that a mass may be formed without molecular induced fields or intermolecular spaces. In this case the molecule as a distinct body is lost in the mass.

When a molecule is relieved from pressure, and consequently split up, each of its constituent parts has a greater qualitative potential, although quantitatively less in dimensions of ponderable matter than the original molecule; hence each nascent molecule has a larger induced field than the original one. It is like breaking up a salt into its acid and alkaline constituents, only all the constituents of the nascent molecules formed under decrement of pressure are wholly derived from the constituents of the original molecule. It is remarkable that cleavage of certain molecules is not an equal division of their positivities and negativities, but

the positivities and negativities tend to separate so that the nascent molecules are either relatively more positive or more negative than the original molecules, and consequently have larger potentials. The chief factors in producing this phenomenon are concentrativeness of positivities and diffusibility of negativities, and the maintenance of the equilibrium of matter and force in space.

When a tube is being exhausted each molecule of residual gas divides into two, or by reciprocal rearrangement of constituents a given number of molecules become a greater number. The increased potentials of the resulting molecules enlarge the molecular induced fields so that the sum of the dimensions of their areas is equal to the dimensions of the tube. This process goes on until the first condensations (§ 18) of matter are reached. A further decrement of the gas produces a condition in which the sum of the areas of the induced fields are not dimensionally equal to the cavity of the tube, and these are conditions pertaining to a vacuum. If the tube is completely exhausted nothing but ether is left.

35. The question presents itself: Why does not the solid part of the earth assume the condition of one large molecule? The answer to this question is that matter tends to form spheres of definite sizes according to the degree of pressure and according to the intensity and character—positivity and negativity—of the potential of the particles; the size of the spheres with their induced fields—at least in gases—being tridimensionally equal for like conditions of temperature and pressure (Avogadro's law). Thus molecules of oxygen and hydrogen may be compressed until their induced fields are obliterated, but when the pressure is removed

each particle of definite and distinctive size according to its potential, will form a spheroidal body, separate from all other bodies by an induced tridimensional field.

The forces that bear on the formation of molecules are twofold in character: (1) The inherent forces of the constituents of the sphere are drawn toward its center; as the sphere is enlarged the attraction toward the center is lessened whilst the forces of the constituent unit at the circumference remain the same. Thus at the circumference local centers of attraction are formed and hence new spheres. The new centers of attraction become the centers of new molecules with inductive potentials, surrounded by induced fields. (2) The grand equilibrium existing between different kinds of matter—solids, liquids, gases, and ether—and between fundamental forces, in relation to space, is preserved by molecules possessing definiteness of potentials, inductive capacities, and material magnitude.

36. *Physical States of Matter.* The forces which determine the physical state—gaseous, liquid, or solid of a substance are as follows:

1. The molecular weight tending towards solidification.

2. The inductive potentials of molecules mutually attracting or repelling:

(*a*) Inductive potentials of negative quality repel each other by inherent repulsion or diffusibility, and by impenetrability of their induced fields, thus tending towards the gaseous state.

(*b*) Inductive potentials of positive quality repel each other by impenetrability of their induced fields, and attract each other by inherent attraction or concentrativeness.

(*c*) Potentials of opposite quality attract each other thus acting with the molecular weight and tending towards solidification.

3. (*a*) The gaseous, liquid or solid state of a substance of molecular inductive potential of negative quality is determined by a compromise between molecular weight—gravitation—and the repulsions of its molecular inductive potentials.

(*b*) The physical state of a substance of molecular inductive potential of positive quality is a compromise between the impenetrability of the molecular induced fields on the one hand, and the mutual inherent attraction of its molecules, and molecular weights on the other.

(*c*) The tendency of matter to form spheres, of definite sizes according to degrees of pressure and quantitative potential, and surrounded by induced fields, is an important factor in determining the physical state of matter (§ 35, § 26).

The *hydrogen* molecule represents in chemistry the unit of molecular weight, notwithstanding, it is shown that in the Crookes tube—a decrement of about one-millionth of an atmosphere—there is a molecule 2,000 times smaller than that of hydrogen, and that this minute body is a carrier of electricity (§ 144). Beyond this decrement there are conditions approaching a vacuum through which electricity does not travel. If this minute carrier of electricity is identical with positive elementary condensations, which are the simplest forms of possible conductors (§ 144) then, the hydrogen molecule has a constituency of about 6,000 ether atoms or units. According to the chemic character of hydrogen these units may be divided into 5,500 positivities and 500 negativities. *If the relative*

number of the units were reversed the molecule would fly to pieces. The molecule of hydrogen has a small gravity potential, and a large inductive potential; and consequently a small ponderable mass, and relatively a very large induced field. Its inductive, polarizing or chemic potential is represented probably by 5,000 ether units to the molecule, or 2,500 to the atom. Compared with the size of the molecule this is a large active polar or chemic potential, but specifically it is smaller than the chemic potentials of molecules of most other substances of positive quality. The small gravity potential in the impenetrable free space of the molecule makes hydrogen a gas of extreme tenuity. Owing to the extent of its molecular induced field and interspace, hydrogen has large specific heat (Fig. 6).

The gravity-units of the *oxygen* molecule may be estimated at 96,000; 50,000 being negative, and 46,000 being positive. In this estimation it is assumed that the gravity-units are those which offer resistance to attraction of a proximate magnet, which is the basis of estimating the size of the hydrogen molecule (§ 144). The molecule of oxygen consisting of two chemic atoms will be formulated as follows:

$$\underset{+}{23000}.\underset{-}{25000} + \underset{+}{23000}.\underset{-}{25000}.$$

The inductive potential of the oxygen molecule in this case is represented by 4,000 negativities. or an active chemic potential of 2,000 negative units to the atom. It is evident that if gravitation, as represented by the gravity-units, had no opposing force, oxygen would be a solid, but it is equally clear that if the negative potential was not opposed the molecules of oxygen would fly apart indefinitely; consequently by a compromise of these forces oxygen is a gas.

The active chemic potential of the oxygen molecule being only 4,000 negative units, it must have a large passive potential. It is probable that of the 25,000 negative units in the atom 10,000 are polarizable and neutralizable by opposing potentials, the active potential of the atom being represented by 2,000 negative units, and the possible passive potential by 8,000 negative units. The 8,000 negative units representing the passive potential being partially or wholly chemically neutralized by a positive atom or atoms, there will be set free a corresponding number of positive units in the atom of oxygen at the opposite pole which may combine with other negatives. Hence oxygen is the medium of combining such negatives as sulphur with such positives as potassium—K_2SO_4 or K_2 O_4 S.

The oxygen molecule has a larger ponderable mass but a smaller induced field than the molecule of hydrogen, with an interspace between the induced fields, the latter being slightly distorted; thus the tridimensional areas of the molecular spaces of oxygen and hydrogen are dimensionally equal (Avogadro's law) (Fig. 6).

The molecule of *water*, H_2O, has a gravity potential of 54,000 units and a small inductive potential of 3,000 *positive units*. It has a small induced field which transmits the vibrations of light. Water has slight cohesive properties, depending on attraction between the inductive positive potentials of the molecules. The conducting properties of water are hampered by the absence of greater molecular polar attraction, the molecules not being arranged in uniform line. By increased intermolecular ether as heat, water assumes the gaseous state. In this condition the tridimensional area of the molecular free space is equal to that of the oxygen molecule or to that of nitrogen. Oxygen, however, has

96,000 gravity units, and the molecule of water has only 54,000, and probably nitrogen has about the same number as oxygen. Hence water in a gaseous state ascends through the atmosphere. It rises until there is lessened resistance to the radiation of heat—to the escape of the intermolecular ether. At this point the molecules approximate, and the ether rises and the water falls.

Carbon must have slight or no inductive potential, slight or no active chemic potential, but *large passive chemic potential*. On the latter depends its quadrivalence.

In determining the character of the unit construction of the carbon molecule the following facts have to be considered: Carbon is a solid, although having only a small atomic weight; it has comparatively slight chemic activity; it has more chemic affinity for negatives than for positives, a fact due to the inherent character of positives; it combines with oxygen with evolution of energy, furnishing a greater quantity of heat than sulphur but less than hydrogen when these unite with oxygen; in this it furnishes a greater quantity of heat than can be accounted for by the union of two negatives, taking the union of sulphur and oxygen as a standard (§ 33); when it combines with hydrogen it requires an extrinsic force of dissociation, and it does not burn ordinarily in an atmosphere of hydrogen. These and certain chemic, physical, and physiologic facts point to carbon being either slightly electropositive or equipotential in its positivities and negativities. In the diamond form it must be hemispherically equipotential. A molecule of carbon composed of two atoms consequently is given the following formula:

$$\underset{+}{18000}\ \underset{-}{18000} + \underset{+}{18000}\ \underset{-}{18000}$$

Evidently the units of the carbon atom are so relatively placed as regards their positivities and negativities, that of the 36,000 units 12,000 free negatives or positives can appear at the surface of the atom when attracted by potentials of opposite quality.

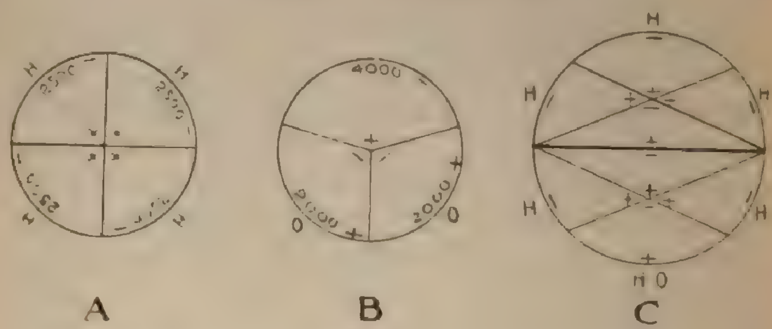


Fig 7.

Differentiated carbon atoms: A, CH_4; B, CO_2; C, C_2H_5HO.

In Fig. 7, A is a representation of a molecule of methane and shows a disturbance of the carbon constituents whereby 10,000 negative units are extrinsically neutralized by 4 atoms of hydrogen. In Fig. 7, B, there are shown to be 4,000 free negative units, the corresponding positives being neutralized by oxygen atoms. When the free negatives are partially neutralized by a molecule of water, which has an estimated potential of 3,000 positives—H_2CO_3—there still remains a potential manifested by an acid reaction. On the other hand, when a carbonate of potassium is formed, K_2CO_3, the 12,000 free units of potassium neutralize the 6,000 units of the radical CO_3 and gives an alkaline reaction. In Fig. 7, C, a molecule of alcohol, C_2H_5, HO, is shown; the center of each carbon atom is represented

as having three positive units to one negative, whilst the union of the carbon atoms, and the union of hydrogen with carbon, are accomplished by differential polar attraction. The hydroxyl is slightly positive, but unites with the active positive pole of the diatomic carbon by means of the passive potential of oxygen. The positive pole of the carbon atom becomes active through the reconstruction of the unit-relativity of the atom.

The alkaline metals are extremely positive in their construction. Amongst the chemic elements they are nearest in their approachment to a positive electric charge, as oxygen or the flourine group is the nearest in approachment to a negative electric charge. The charges of positive and negative electrification to be maintained have to be insulated, and so for the purpose of maintaining their separate potentials the chemic charge of positivity represented in an alkali, and the chemic charge of negativity represented in oxygen, have to be insulated. So intense is the attraction between oxygen and the alkalies that the latter have to be submerged in a liquid—coal oil—that does not contain the former, or kept in an atmosphere of hydrogen, for the purpose of preventiug union.

The *potassium* molecule consisting of two atoms will have a constituency of 240,000 units. We will say that 126,000 of these are positive and 114,000 are negative. This will give a molecular inductive potential of 12,000 positivities, or 6,000 free chemic units to the atom. The 12,000 units of positive potential produce ether polarization in the induced field or vibratory space of the molecule, which by its impenetrability repels molecules of like potential to the extent of its area. Considering the induced magnetic field as part of the

molecular body, the molecules of potassium are mutually attracted by 12,000 units of positive potential, and the condensation is aided by the action of the earth's forces on the 240,000 gravity units or molecular weight.

As *copper* is frequently used as a conducting agent, it will be considered here. It is also representative of a class, the members of which, although positive in their potentials, are evidently not extreme in their positive characters. The number of units in the molecule of copper may be said to be 384,000; the positivities being 195.000 and the negativities 189,000. Thus its molecule will have an inductive potential of 6,000 positivities, or 3,000 actively polarizable units to the atom. The induced field is small and the relative size of the ponderable molecule to its free vibratory space makes it a good conductor of electricity.

Zinc, to which reference will be made in this work, has an estimated number of 390,000 units to the molecule. The positivities of the molecule are estimated at 201,000, and its negativities at 189,000, giving a molecule of two atoms an inductive potential of 12,000 units of positivity, and an active chemic potential of 6,000 positivities to the atom. It is a more positive molecule than the copper molecule, but it is not so good a conductor owing to the relative size of its ponderable body to its induced field.

Owing to great distortion of the molecular induced fields the interspaces are small or even absent in positive elements.

In making comparative estimations of the number of units in molecular construction, and stating the comparative potential of molecules, there is no intention other than to illustrate a principle of positive and negative unit representation, and to show that porpor-

tional representation of positive and negative units in atoms is the only possible explanation of their affinities.

37. Avogadro's law is as follows: "All gases under the same conditions of pressure and temperature, in unit volume, have the same number of molecules." This means that the size of the molecule and the size of the intermolecular space added together give dimensions which are the same for all gases, under the same conditions. Let us call this tridimensional area the *vibratory space*. Then, as the size of the molecule must be in direct proportion to its molecular weight, and as the size of the intermolecular space must be inversely proportional to the molecular weight (if immolecular neutralization be constant), it follows that if the molecule be increased in size and relatively reduced in inductive potential until it fills nearly the whole molecular vibratory space, it is a liquid, and any additional increase in dimensions makes a solid. From which it must be inferred that the differences in the size of molecules is a factor in determining the fundamental difference in the physical states of matter. The law may be framed thus: *The vibratory spaces of all molecules of gases have the same tridimensional areas, providing the conditions of temperature and pressure are the same.* Whence these corollaries: 1. Molecules can be increased in size until they fill the vibratory spaces, when they lose their molecular character, which becomes immerged in that of the mass. 2. The number of chemic atoms of elementary substances to the molecule depends upon this law. However, the size of molecules is subject to the forces that determine the physical state of matter (§ 36); and the increase of molecular quantities beyond specific dimensions must be accomplished by extrinsic pressure. Molecules

differentiate intrinsically. In dimensions; in inductive potential; and in relative unit-placement—in immolecular and exmolecular unit-neutralization. Avogadro's law evidently does not apply to molecular solid conditions, but as unit associations were effected primarily under gaseous conditions elementary molecules of the solid and liquid states bear the impress of the law.

By the above considerations there is furnished a new definition of a molecule, viz.: *The smallest physical particle of matter which can exist as a vibratory entity.*

Electro-chemic series as arranged by Berzelius.

Elecro-negative.

Oxygen.	Titanium.	Zinc.
Sulphur.	Silicon.	Manganese.
Selenium.	Hydrogen.	Uranium.
Nitrogen.	Gold.	Cerium.
Fluorine.	Osmium.	Thorium.
Chlorine.	Indium.	Zirconium.
Bromine.	Platinum.	Aluminium.
Iodine.	Rhodium.	Didymium.
Phosphorus.	Palladium.	Lanthanum.
Arsenic.	Mercury.	Yttrium.
Chromium.	Silver.	Glucinum.
Vanadium.	Copper.	Magnesium.
Molybdenum.	Bismuth.	Calcium.
Tungsten.	Tin.	Strontium.
Boron.	Lead.	Barium.
Carbon.	Cadmium.	Lithium.
Antimony.	Cobalt.	Sodium
Tellurium.	Nickel.	Potassium.
Tantalum.	Iron.	

Electro-positive.

Rearrangement of the elements has been made as follows:

— F, Cl, Br, I, O, S. ....Argon, Helium, etc.................
Au, Pt, Hg, Ag, Cu, H, Pb, Ni, Co, Cd, Zn, Mn, Al, Mg, Ca, Sr, Ba, Li, Na, K, Rb, Cs. + . From the stability of its compounds, from its diffusibility and gaseous state, and from its chemic activity and valency, oxygen should be considered as the most electronegative element. Moreover, it is electrified directly in the presence of other elements—showing relative affinity—by the positive current, and carried towards the negative pole (§ 61); on the contrary, iodine is influenced inductively.

Electro-chemic potential is of two characters; it is relative and it is specific. Copper is relatively more negative than zinc, but both are specifically positive, *i. e.*, each contains more positve than negative units within its chemic atom or molecule.

The electro-chemic series may be arranged in the shape of a globe, potassium representing the north pole and oxygen the south, while such substances as tellurium, silicon, etc., approach the equator; whilst carbon may be equatorial. Hydrogen is located distinctly within the northern hemisphere and iodine is well within the southern, the other elements being relatively placed as in the table. When measured by an electric unit—the ether atom—all substances are specifically positive or negative in their polar or chemic potentials, except the argon group and carbon which may be on the equator, thus furnishing certain distinctive characteristics. The relative position apparently varies with the temperature, thus carbon at high temperatures decomposes potassium carbonates:

$$K_2\,C\,O_3 + C_2 = 3CO + K_2$$

The chemic reactions taking place according to the formulæ are misleading as to affinity. Potassium is inclined towards solidity and oxygen towards tenuity or the gaseous state. The high temperature tends towards decomposition, and as carbon is capable of forming a union with oxygen as a gas, it merely assists in the dissociation.

It will be well to follow the ether changes that take place according to the above formulæ. Potassium carbonate, $K_2C\ O_3$, has large molecular weight—183—the atomic potentials are dissimilar, and the sum of their positivities slightly exceeds the sum of their negativities. The molecule has a small inductive potential and a small distorted induced field, therefore $K_2C\ O_3$ is solid. In the retort the ether by its impenetrability presses the molecules apart, and this is followed by groups of units dissociating as submolecules, so as to maintain an equilibrium. As the submolecules part their attractions diminish, attraction being inversely proportional to the square of the distance between them; at the same time the total potentials of the molecules increase, with proportional increase of the dimensions of induced areas within which is a greater amount of polarized ether. As the ponderable masses of the molecules become smaller they are either more positive or more negative than original molecules. Under these conditions oxygen has a tendency to free itself from potassium and enter into union with a less ponderable and a less positive element, and the presence of carbon furnishes this opportunity. The reactions under the influence of ether energies are from lower to higher potentials from larger to smaller ponderable bodies. The forces tend towards the separation of molecular constituents, and

to the formation of more molecules with larger potentials, with the result of polarizing the heat-ether or molecular ether current (§ 22), which in the polarized condition occupies less space, thus relieving the pressure. In the first formulæ—$K_2\,CO_3 + C_2$—there are shown only two molecules; in the second there are four—$3CO + K_2$. Oxygen therefore parts with potassium not because of a greater affinity for carbon, but because of other laws. At a higher temperature the molecules will dissociate further, and there is no doubt but there are temperatures which will dissociate molecules until the elementary condensations are reached. The conditions attending high temperatures are identical with those of great decrement of pressure in gases, the difference being only in the means of overcoming the pressure. In the former the pressure is overcome by the ether-stream, in the latter it is overcome by the impermeability and rigidity of the glass of the tube; in both the interspaces are enlarged with similar molecular results.

38. *Differential Character of Molecules.* Molecules of large ponderable dimensions and of about equal positivities and negativities, when polarized, may manifest cohesive properties by polar juxtaposition, without interposition of an intermolecular induced field. They are opaque because they have no intermolecular ether, and are non-conductors because, having their poles fixed, they do not vibrate. Shellac, resin, wax, gutta-percha, and metallic oxides are composed of this class of molecules.

Molecules having equal positivities and negativities in their construction and consequently slight qualitative potentials, may be polarized with intermolecular fields (§ 149, § 168); they are transparent because they

have intermolecular ether, and are non-conductors because they do not vibrate or vibrate slightly owing to their fixed polarization. Glass, mica, and diamond are types of substances whose molecules belong to this class.

Chemically elementary substances whose molecules have a potential of positive quality, such as the metals, are good conductors and are opaque. Their molecules repel each other to the extent of their induced fields, and attract each other by positive concentrativeness. They are sensitive to vibratory influence because of the potentials, and are opaque because of the extreme distortion of their induced fields and because their vibrations interfere with the vibrations of light (§ 275). The relative size of the ponderable molecular body to the free vibratory space and the relative fixity of the molecule give the substances the property of conduction in a superior degree.

Molecules having strong negative potentials, and small or medium gravity attractions, repel each other, have no cohesion, have free intermolecular ether, and consequently are transparent. They are non-conductors or possess the conducting property but slightly owing to the intermolecular spaces being greater than the molecular vibratory swing (Figs. 5, 6). This class is typified by the molecules in elements of dry air. Molecules of strong positive potentials with very small gravity attraction have characteristics similar to those of this class.

39. The properties of matter rest upon the fundamental principles of attraction and repulsion inherent in ether atoms; upon the concentrativeness—attraction—of positive, and diffusibility—repulsion—of negative units; upon attraction between positivities and nega-

tivities; upon the indestructibility and impenetrability of the atoms of ether or unit-matter, and indestructibility and impenetrability of unit principles; and upon the grand equilibrium of matter and force in relation to space.

The neutralization of all force within the ether molecule, the preservation of impenetrability, and the assumption of the globular form, are the bases of molecular ether properties or absence of properties. In the separated ether atoms there resides a potentially free force, and in the various condensations of matter the same immolecularly free force represents the unit-potentials of all other forces. The induced fields of electric potentials are identical in principle with, and are representations of the induced fields of all potentials. Induced forces possess the property of impenetrability, but disappear when the primary potentials are neutralized.

The quantitative and qualitative potentials of ponderable molecules; the relative position of the units in molecular construction; the relative amount of ponderable matter in molecules; the relative dimensions of molecules to the free or vibratory spaces or induced polarized fields; the spherical form of molecules with the property of differentiating their poles; the polarization of molecules and consequently of masses; the disruption of molecules by stronger polar attractions—chemic action; their modification by pressure or temperature into smaller or larger molecules; the distortion of the tridimensional areas of their induced fields by pressure; the interspace between the induced fields of certain potentials; and the homogeneity or heterogeneity of molecules in the physical mass, involve secondary principles depending on the inherent attrac-

tion and repulsion of units, and affording bases of further differentiated action.

It must be clearly borne in mind that forces act and react in inverse proportion to the square of distance. Thus, according to this law, the forces within an ether molecule are not affected by the inductive potential of the earth—gravitation; but they are affected—polarized—by the inductive potential of a ponderable molecule, and they are completely disrupted by other forces. On the other hand, according to the same law the inductive force of the earth takes possession of the free or incompletely neutralized forces of a complex molecule; hence the ponderable molecule. If a complex molecule of equal positivities and negativities was sufficiently distant from disturbing forces such as those of the earth, it would be a self neutralizing body.

From these principles spring the myriads of electric, chemic, physical, and physiologic phenomena; and by these the grand equilibrium of matter and force is maintained in their relation to space.

40. *Boundary between ether and ponderable matter.* Is this boundary ever crossed? Does ether assume the more complex form, or is ponderable matter ever simplified as ether? When ether is considered as the simplest form of matter, theoretically the question should be answered in the affirmative. Practically this is difficult, perhaps impossible, of demonstration. The cathode rays are subnormal molecules charged negatively. It is possible and probable that the charge temporarily is associated as a unit-atom in the subnormal molecule, which is of intense positive potential, to be again dissociated at the bombarded spot where it meets the positive ether. Here is a synthetic followed

by an analytic reaction between ether and ponderable matter. Hence the question of the relationship of all electric charges to the body charged presents itself. The conception is reasonable that between electric charges and the units of ponderable matter of intense chemic potential and of opposite quality to the electric charge, there may exist an intimacy of the same character as the relationship between the constituents of molecules. To maintain the universal equilibrium of matter and force a certain relative placement of units, is imperative. The relative placement gives potential based upon the distance asunder of neutralizing units. The aggregate distance, the aggregate potential, and the relative placement in its entirety, never vary; a disturbance of either at a certain point is a disturbance of all, and is equilibrated by a disturbance of equal value at a distant point.

CHAPTER III

Galvanic Current

41. When two substances having different chemic potentials (§ 11) are held in the same solution, or are otherwise in contact, they tend to reform or rearrange their atoms at a lower potential. This law applies to all purely chemic analytic reactions. The difference in the sum of the potentials of the newly formed substances and the sum of the potentials of the substances disintegrated constitutes a newly formed potential of heat or electricity. When substances reform under a lower chemic potential, the potentials of the atoms are partially neutralized. Their potentials being lessened, the induced magnetic fields of the molecules are lessened and the polarized ether in the induced fields is decreased. The part of the polarized ether in the fields which is set free becomes a current of electricity or radiates as heat (§ 103, § 67).

42. When zinc and dilute sulphuric acid are brought in contact sulphate of zinc and hydrogen gas are formed with the evolution of heat. The amount of heat evolved represents the difference of potential between the old and newly formed chemic substances. Thus: $Zn_2 + (H_2SO_4)_2 = (H_2)_2 + (Zn\ SO_4)_2 +$ Heat.

The ether changes are, decrease of the polarized ether in the molecular induced fields (§ 19), and increase of the depolarized intermolecular ether, the latter

finding a place in other intermolecular spaces. The molecular disturbance thus created manifests itself as heat (§ 126). In the transaction hydrogen, by changing its physical state from liquid to gas, absorbs ether into its induced field, but the difference in the positivities of zinc and the positivities of hydrogen is so great as to allow the elimination of polarized ether as heat, notwithstanding that there is absorption by the physical change.

43. If there be immersed in dilute sulphuric acid a copper plate, a short distance from the zinc plate, at the same time connecting the two plates—copper and zinc—with a conducting wire—usually formed of copper—an electric current will partly take the place of the evolved heat. To understand the causes of these different phenomena—heat and electricity—it is only necessary to follow the ether from its polarized state in the induced fields of the molecules in its course towards heat or electricity. It has been stated that ether is polarized by the potential of the molecule (§ 19), and when the potential is lessened polarization of ether is lessened. Now, *polarization is the first step in disintegration;* when the conditions are not favorable to complete disintegration depolarization takes place and the molecule of ether becomes free in the intermolecular spaces, where it disturbs the equilibrium between ether and matter, and the disturbance constitutes the radiant energy called heat (§ 126).

44. Comparatively, copper is electro-negative and zinc is electro-positive: That is to say, copper atoms have a larger number of negativities in their construction than the zinc atoms, and zinc atoms have more positivities in their construction than the copper atoms (§ 36). The zinc plate will attract negative atoms of ether;

and the positive atoms of ether will seek the opposite route. Specifically both copper and zinc are electro-positive, but zinc is more positive than copper (§ 37), hence the copper plate is passive in directing the course of the current.

Just at the moment of the polarized ether molecule being set free, by the different attractions of the zinc and copper plates dissociation is completed, and the positive ether atom flies to the more negative copper plate, and the negative ether atom adheres to the more positive zinc plate. The copper and the zinc plates thus become electrified just as the glass and resin become electrified by friction (§ 3). The uniting of the two plates by means of conductors provides a pathway whereby the positive electrification of the copper plate and the negative electrification of the zinc are neutralized with less resistance than through the cell and by radiation as heat. These electrifications furnish a constant current which has been named the *galvanic.*

45. It has been shown that the foregoing chemic analytic changes resulted in the formation of hydrogen gas and sulphate of zinc. The sulphate of zinc is held in solution by the fluid of the cell. The hydrogen, being electro-positive—having more positivities than negativities in its atomic construction—seeks the copper plate, for the same reason that the positive ether seeks it, on the surface of which it may be seen. The zinc sulphate held in solution may be split up, the zinc being also deposited on the copper plate, and the radical SO_4 seeking the zinc plate. The initiatory force within the cell is the difference of potential of sulphuric acid and zinc sulphate, but the direction of the course that elements take is determined by the difference of potential of the zinc and copper plates.

The differences of potential dominate all cell-action. These include all the changes that take place, in this instance, in the transformation of chemic potential into an electric force.

The galvanic current, as it depends on the chemic action in the cell, is *continuous, constant or uninterrupted.*

46. The conception is clear that electrification is carried over a conductor by means of molecular vibration (§ 6), and that the vibrations are trapeziform in character and in rhythmic order (§ 7).

Fig. 8.
Trapeziform Molecular Movements.

In Fig. 8 there is represented a number of longitudinally arranged molecules of a metallic wire. The positive ether atom is entering at the left and the negative at the right. The law that *likes repel and unlikes attract* (§ 4, § 23) must be kept in view in order to understand the molecular movement. The first molecule is seen to be electrified positively as it swings to the left; it is then attracted by the negative current in front, which is indicated at the right of the diagram. The extreme right molecule is electrified negatively as it swings to the right, and is then repelled by the negative current behind it and attracted by the positive current in front. When the left molecule swings to the right it meets the non-electrified second molecule, which it electrifies, and becomes itself non-electrified, when it rebounds to the left and is reloaded; and the converse process occurs at the negative end. The

unloading is caused by the attractions and repulsions of the current, and the *trapeziform* and rhythmic molecular movements are fully accounted for by the same forces. The molecules shown at the ends of the figure are in the position of being reloaded respectively by positive and negative ether, the second and each alternate molecule are in the position of unloading, and the molecular polarization has disappeared. The rebound of the molecule to its normal position is effected by the tendency of the molecule to resume its proper position in the equilibrium of matter; but the rebound is assisted or retarded by the attraction and repulsion of positive and negative ether, a fact which gives an important insight into molecular vibration. In all metallic conductors the atoms are electro-positive, having more positive units in their construction than negative. When a molecule of copper is unloaded as represented in the diagram, it is attracted by negative ether and is thus assisted in its rebounding movement. On the other hand, the rebound in the positive part of the circuit is effected by the molecule assuming an equilibrated position. The effect of these influences is to retard the molecular rebound at the positive end of the conductor and to hasten the rebound at the negative end. Therefore the negative current under these circumstances would travel faster than the positive but for reverse influences during the loaded or forward movements of the molecules. However, positive and negative ether units differ in their kinetic potency through their inherent properties, thus differentiating the speed of currents. The forces in a current of negative electricity are the inherent repulsion—diffusibility—of its units, and the attraction between these and the positive units, the forces mutually supporting. On

the other hand, the forces in a current of positive electricity are attraction—concentrativeness—between the positive units, and attraction between these and the negative units, the forces mutually opposing. Hence it is clear that the negative units will travel the greater part of the circuit, and will constitute the current of electricity in the majority of instances. In the vacuum tube and in the electrical phenomena of muscles, etc., the facts support this conclusion. However, media may be of such a character as to favor the flow of the positive current as shown in the differential manifestations of sparks; and it may be accepted as a rule that the ether units of electric currents meet and neutralize at the point of greatest resistance in the circuit as shown by the phenomena of electric lights. It must be borne in mind that positive units repel each other only through induced fields, and that induced fields can only exist by the intervention of polarizable material, *i. e.*, material not directly charged nor already under inductive forces of stronger potentials. Again, the natural vibratory gait of conducting molecules may determine the current-speed; and in this case positive and negative electricity will have the same frequency of vibration through the common medium.

47. It is clear that neutralization of the positive and negative ether will take place in various parts of the circuit, the location depending on the uniformity of resistance and perhaps on the degree of positivity or negativity of the conducting medium or media. The location of the neutralization point will depend upon the relative fixity of conducting molecules, and upon the method of conduction whether by molecular vibration as in metals, or by catephoretic action in which

the particles are carried along with the current as in sparks and in some liquid media.

Fig. 9 represents the points of neutralization in a circuit with different resistances. The dark part of B, represents the negative current and the light part the positive. In A each line denotes a file of molecular carriers, and the irregular line the meeting of the two currents. At the point of neutralization the ether

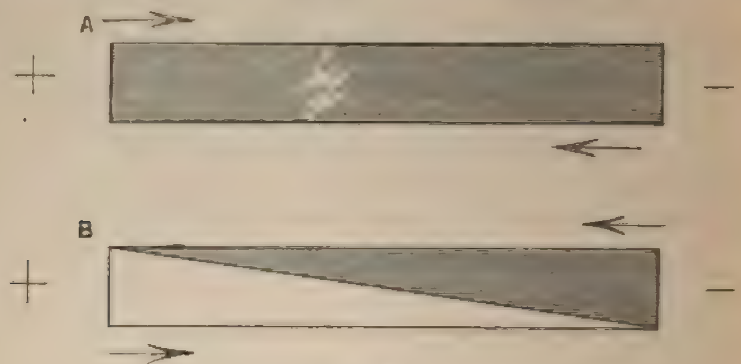


Fig. 9.
Neutralization of Current.

atoms unite and form molecular ether which manifests itself in the radiation of heat or light.

48. In measuring the galvanic current by the galvanometer it is found that *all parts of the circuit show the same amount of current-force.* The potentials are measured by the forces of the positive and negative ether atoms which are moving in opposite directions, consequently the kinetic influences of the positive and negative ether, on a sensitive magnetic needle, which is of constant and fixed polarity, are uniformly directed. It is clear that the sum of the forces exercised in the same direction at any point of the circuit depends upon the total quantity of ether in the current, and is inde-

pendent of the variation (§ 105) in its quality, when influencing the qualitatively fixed pole of the needle.

49. The ether atoms constituting the current meet, neutralize each other, become molecular ether, and the electric force is transformed into heat. The question arises: What becomes of that part of the force which is thought to be spent on resistance—*i. e.*, that force which represents the difference between the electromotive force of the cell and the amount of the current? If the chemic elements in the cell act independently of the circuit, chemic action is directly transformed into heat. Connecting the copper and zinc plates with a conducting wire is merely providing a path, wherein the separated ether atoms unite with less resistance than they have to overcome in their direct union and radiation within the cell. Consequently the raising of the resistance without the cells increases the heat within the cell, if chemic action remains the same. If chemic action takes place only when the circuit is made, it means that such action is not powerful enough to overcome the resistance that molecular ether meets in its radiation as heat, consequently increase of external resistance lessens chemic action within the cell.

The question can be stated as follows: As the result of chemic action polarized ether is set free. The ether can follow one of two courses. It can depolarize and radiate as heat, thus overcoming the resistance of the fluid in the cell, or assisted by the difference in the potential—electro-positivity and electro-negativity—of the plates, it can dissociate, and its atoms following the circuit, and uniting in some part of their course, be transformed into radiant energy. Consequently by increasing the resistance of the circuit ether is forced on the other track, radiating as heat within the cell—

or it may retain its polarized position in the molecular induced fields; by decreasing the resistance of the circuit the heat of the cell is lessened and the electric current is increased.

50. The apparatus necessary for the production and application of the galvanic current consists of the following parts: A *cell*, generally a glass jar, in which there are *two plates*—an *electro-positive* and an *electro-*

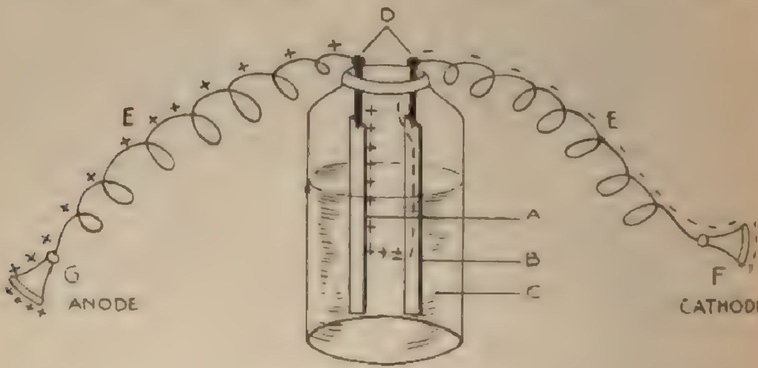


Fig. 10.

Galvanic cell: A, copper plate, electro-negative attracting positive ether; B, zinc plate, electro-positive attracting negative ether and acted upon chemically by the electro-negative fluid; C, electro-negative fluid; D, binding posts; E, E, conducting wires; G and F, electrodes, anode and cathode. The ether is split up on the surface of B, and the atoms follow their course to G and F, which must be connected by a conducting medium or media.

negative, surrounded by an *electro-negative substance*—usually in solution—capable of acting chemically on the electro-positive plate. Each plate has a *binding post* to which is attached a *conductor*, commonly composed of copper wire, and which is covered with insulating material. The conductor ends in a *tip* suitable for insertion into an *electrode*, the latter being a conductor varying in size, shape and material, suitable for applying the current to numerous surfaces. The electrode

attached to the electro-negative plate is called the *anode*, and through this the positive current enters the part to which electricity is applied. The electrode connected with the electro-positive plate is called the *cathode*, and through this the negative current flows.

Electrolysis

51. When a galvanic current is passed along a metallic conductor the changes produced partake of a vibratory and transient character. The effects produced by the current on a fluid are usually permanent and characterized by chemic dissociation. If, for instance, two plates of platinum to which are attached the conducting wires of a galvanic battery are dipped into water, the water thus forming part of a circuit, the current on passing through the water will decompose it, with the result that bubbles of oxygen appear on the positive plate or electrode, and bubbles of hydrogen on the negative plate. Pure water is with difficulty decomposed, but if sulphuric acid or certain salts be added to the water, electrolysis is greatly facilitated. If the current be passed through a solution of sulphate of copper, the result will show copper on the negative electrode, but the sulphuric acid which is set free, although attracted towards the negative pole, will remain in solution. Other substances under like conditions will show analogous results from the action of the current.

If instead of platinum, plates of zinc or copper or other material having strong potentials be used, the newly formed sulphuric acid or other negative elements attack the positive electrode, and a salt is formed.

The action is entirely chemic and is not produced by the current.

The following table shows the electrolytic results of substances held in solution.

Positive pole.	Electrolyte.	Negative pole.
O_2.	$(H_2O)_2$.	$(H_2)_2$.
SO_4.	Cu SO_4.	Cu_2.
CL_2.	(Na Cl)$_2$.	Na_2.
I_2.	(K I)$_2$.	K_2.
acid.	salt.	base.

The proportions of the elements decomposed are equal to the ratios in which the substances combine: thus, the electrolysis of water results in the evolution of 8 grs. of oxygen to 1 gr. of hydrogen, or of these elements in the ratio of 8 : 1, respectively.

The secondary results do not strictly belong to electrolysis, and vary with the character of the decomposed substance and with that of the electrode. Thus, chlorine is emitted as a gas if a platinum electrode is employed; but with a copper electrode, chloride of copper is formed. Sodium going to the negative pole decomposes water and forms an oxide, setting hydrogen free. In the decomposition of a solution of potassii iodide, iodine and oxygen go to the positive pole, and potassium and hydrogen to the negative, the potassium again combining as an oxide or hydrate. The iodine colors the solution around the positive pole and is an excellent means of distinguishing the poles.

52. The solution upon which the current acts has been named an *electrolyte*, the electro-negative elements accumulating at the positive electrode have been termed *anions*, the electro-positive elements at the negative electrode are called *cations*, and both are called *ions*.

The phenomena connected with the action of the galvanic current in decomposing substances into ions are included under the term *electrolysis*.

The definition of *ion* may be given as a *free atom dissociated by means of an electric current or other extrinsic force, which has assumed the molecular condition, and which is subnormal in size and supernormal in potential*, the standard of normality being the equilibrium of its environment.

53. When the galvanic current passes through a fluid the ether atoms may be carried along by means of the same rhythmic molecular vibrations that take place in a metallic conductor (§ 7, § 46) or by other means to be considered (§ 59—61). The results, however, are different after neutralization. When positive and negative ether atoms meet and form molecules, their disposition depends on the resistance encountered. When there is a metallic conductor they radiate as heat, that being the direction of least resistance. When there is present any substance through which by a change in its physical state or chemic construction heat is absorbed—that change offering less resistance than heat radiation—the ether molecules concentrate their force on the changeable substance and disrupt or volatilize its molecules. An ether molecule concentrated on a molecule of a substance must be equal in temperature to an immense amount of heat applied to the substance at large. The first step in electrolysis is *heat applied to molecules individually, and the process is completed by the inducing influence of the current*, as shown in Fig. 11. The molecules of ether become polarized in the induced fields of ions and represent the transformed potential.

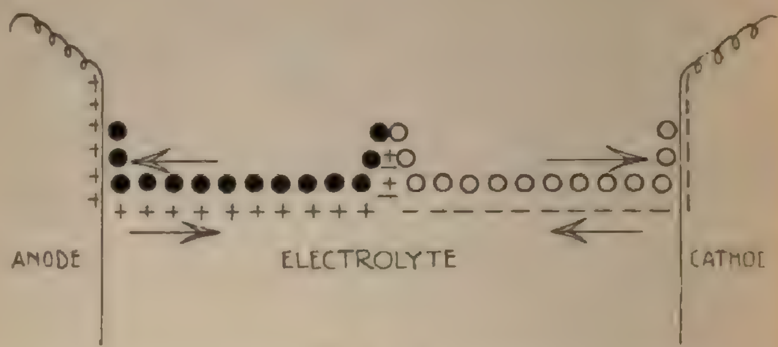


Fig. 11.

The nascent molecule of ether is shown as entering the ponderable molecule in the electrolyte and disrupting it; O, electro-positive, and ●, electro-negative atoms or ions seeking their respective poles.

The electric resistance of fluids being immensely greater than that of the conducting wire, the whole electric current is transformed within the electrolyte. It is probable that the parts of the electrolyte offering most resistance are its borders, owing to the difference in the normal vibrations of the plates and of the electrolyte. At whatever part of the electrolyte decomposition takes place the ions are carried to their respective poles, *not by displacement*, but by the attraction and repulsion of the current acting upon their increased potentials. The process by which they are carried to the poles is identical with that of driving a soluble salt of mercury from the positive and a solution of iodine from the negative pole by *induction* (§ 59—61).

If the electrolyte contain such a substance as hydrochloric acid $(H\ Cl)_2$, the ions being both gases, hydrogen, H, and chlorine, Cl, the amount of electric force spent in decomposing the acid will bear a direct proportion to the heat that has been absorbed in the action; or to the difference between the potential of the ions and the potential of the electrolyte. If the electrode is

acted upon by chlorine, the action is not electrolytic and need not be considered.

54. The ether changes that take place are as follows: Separated ether atoms unite to form ether molecules; the ether molecules as heat acting on the molecules of hydrochloric acid (or other electrolytic elements), split them up, at the same time the attractions and repulsions of the current separate the chlorine and hydrogen, the ether remaining polarized in the induced fields of these ions. When there are secondary reactions, such as potassium and water acting on each other, the chemic potential of water has to be considered as assisting the action of the current, by depreciating a polarized potential.

The law governing electrolysis may be stated thus: The difference between the potential of the electrolyte and the potential of the ions is in direct ratio to the amount of the decomposing current.

When a molecule is split up into atoms by electrolysis the latter are ionized. The ions absorb energy according to their polar potentials or chemic valencies. Thus the ionization of two atoms of hydrogen absorbs an amount of energy equal to the amount absorbed by one atom of oxygen. That is to say, ions have a definite increased potential, have a corresponding increased polarization of ether in their induced fields, and the increase is according to their valencies. An atom dissociated from a molecule is supplanted by a definite amount of polarized ether. The dissociated ponderable atom was within the ponderable body of the molecule, and the polarized ether is within the induced field of the ionized molecule.

It must be kept in view that any fluid within the circle will constitute an electrolyte. Thus the fluid in

the meshes of a sponge or other electrode may hold in solution a substance convertible into ions.

Polarized Current

55. As a result of electrolysis the ions accumulate at electrodes. Their further progress is barred by the solid character of the circuit. They have gained a chemic potential at the expense of the electric force, and their tendency is to reunite under a lower potential. Thus chlorine, iodine, acids, and other chemically negative elements collected at the positive pole, and the alkalies, metals, and other chemically positive elements at the negative pole, because of their mutual attractions, will unite when the conditions are favorable. The union will take place according to the law of least

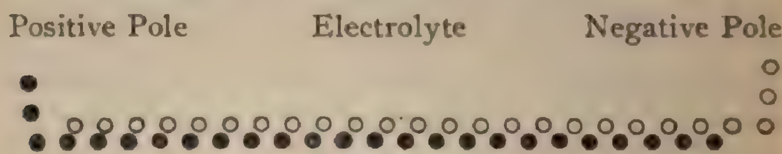


Fig. 12.
Illustration of the Polarizing Movement by Displacement.

resistance. Whether this change is accomplished by displacement, or by positive and negative ions actually moving towards each other and meeting somewhere in the electrolyte, cannot be proved. The more the electrolyte approaches solidity, the more favorable are the conditions towards union by displacement; the more the liquid approaches the gaseous state, the more favorable the conditions towards actual transverse. An electric spark, the cathode rays, cataphoresis and electrolysis are instances of actual transfer of matter taking place during current action, whilst the Daniell cell

probably furnishes an instance of a current produced by successive atomic displacement (§ 111).

When by the chemic union of the ions ether is set free it is influenced by the attractions and repulsions of the electro-positive and electro-negative plates in the batteries just as in the case of the ether set free at the zinc plate by the action of sulphuric acid. However, there is the important difference of the polarized current being in the opposite direction to that of the original current. Thus as the ions accumulate the polarized potential tends to obstruct the original current, the latter decreasing accordingly, and as the ions move toward the point of union they assist in giving direction to the polarized current.

The polarized current is easily demonstrated by passing the galvanic current through an electrolyte of water and sulphuric acid, using platinum electrodes. The original current will be found to decrease as the ions accumulate, the ions forming an embankment of resistance to the original current. If the battery is then removed but the circuit maintained, the galvanometer will show a current in the opposite direction which will gradually decrease as the ions reunite, the differential polarity of the accumulated ions determining the direction of the current. Thus the positive ether will seek the negative ions, and the negative ether will seek the positive ions, the embankment of ions and the plates in the cell acting together in directing the current.

56. The following tabulation expresses the various transmutations of force connected with the galvanic current.

Battery Action

Chemic potential transformed into electric action—

ether set free from the polarized fields of reacting molecules.

Electrolysis

Electric action transformed into chemic potential—ether absorbed into the polarized fields of molecules or ions.

Polarized Current

Chemic potential transformed into electric current—polarized ether again set free.

CATAPHORESIS

57. When two fluids of different densities are separated by an animal membrane transfusion takes place, and the movement is greater from the less dense to the denser fluid. The phenomenon has been termed osmosis. The causes of osmotic action are as follow:

1. A difference in the quality or quantity of the potentials of the molecules of the two fluids produces an attraction identical with chemic affinity but not sufficiently strong to effect atomic dissociation. That two substances of strong chemic affinity will mix without chemic action occurring is easily demonstrated. Thus oxygen and hydrogen gases may diffuse without chemic action taking place. But if the union is stimulated by electric action, which causes molecular polarization—a step towards dissociation—the effect is instantaneous.

2. The difference in the dimensions of the intermolecular spaces of two fluids is a disturbance in the equilibrium between ether and matter—a difference of physical potential. Transfusion tends to readjust the equilibrium.

3. The atmospheric pressure on the surfaces of the

two fluids is a cause. Transfusion apparently occurs in opposition to this force as one fluid rises above the level of the other, but this merely indicates that the two other forces are strong enough to act against the last.

58. Osmosis may be assisted, retarded or prevented by the electric current, or if the current is sufficiently strong transfusion may manifest itself in the opposite direction to the ordinary osmotic flow. Furthermore electric osmosis occurs when the same liquid is on both sides of the porous partition, while simple osmosis requires different fluids. The phenomena embraced in electric osmosis have been termed *cataphoresis*.

Definition. For the purposes of this work cataphoresis is defined as the transposition of substances in solution, by the electric current, without chemic decomposition. The line is thus distinctly drawn between cataphoresis and electrolysis, the latter being chemic and the former physical in character. Whether a salt is subject to electrolysis or to cataphoresis depends on the strength of the current, on the stability of the salt, and on the electric resistance of the medium.

Cataphoresis takes place from both poles. Thus a solution of iodine placed on the negative electrode, or a soluble salt of mercury placed on the positive electrode, will be carried toward the opposite pole by cataphoretic action.

59. Cataphoresis is accomplished by two methods:

1. A molecule may be directly electrified and carried toward the opposite pole. Particles of carbon from the point in an incandescent lamp are carried from the positive to the negative pole, and particles of air at either pole are electrified and form

a spark. These phenomena are based on this method of cataphoresis.

2. Cataphoresis is accomplished by ***induction***. The current consisting of moving electrified particles, or of electricity moving by molecular vibration, causes an opposite current of other particles by induction.

If there be intercalated in a circuit through which a current is flowing, a strip of sarcous element of muscle, the strip at the same time being observed under the microscope, there will be seen to be a swelling of the cathodal and a shrinking of the anodal end. This is called Porret's phenomenon in living muscle. It demonstrates that cataphoresis is practicable in a semi-fluid material.

60. For practical purposes cataphoresis can be divided into:

1. *Anodal* cataphoresis, embracing the diffusion by induction of solutions of alkali, metallic, and alkaloidal salts and other electro-positive compounds. Electro-negatives under certain conditions may be carried from the positive pole by direct electrification. Water being electro-positive (§ 36) is carried from the anode by induction.

2. *Cathodal* cataphoresis, embracing the diffusion of iodine and other negatives from the negative pole by induction. Electro-positives may be carried by direct electrification (§ 237) from the negative pole. Practically, cataphoresis is accomplished by induction—positive elements from the positive pole and negative elements from the negative pole.

When the current enters a liquid some of the molecules are charged. The charge and the electrically opposite atoms of the electrified molecules are attracted.

From this point the current follows one of two courses. It carries the molecule along with it—cataphoresis—and by meeting the opposite current and neutralizing it disrupts the molecule by heat—electrolysis—the atoms then seeking the poles inductively according to their positive and negative potentials; or, the current by means of molecular vibration is conveyed to the point of neutralization where it will act as in electrolysis. It is apparent that the course depends entirely on the molecular character of the medium.

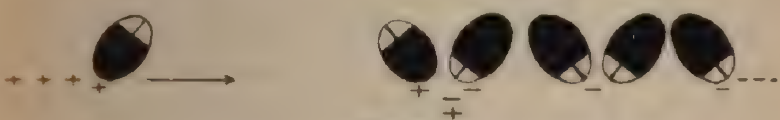


Fig. 13.
Transmission by Direct Electrification of Molecules and by Vibration.

61. Direct electrification of molecules depends upon the relative atomic weights and qualitative potentials of the molecules present in the solution, the current selecting molecules of opposite potentials and of small weight. The smaller the atomic weight, the less the resistance offered. The molecules selected will also depend on the size of the current (§ 237).

In Fig. 13 there are represented molecules of water, no other element being present, the larger atom being oxygen, and the smaller atoms hydrogen. When the positive current enters the water it electrifies the oxygen atom which forms the greater part of the molecule. The hydrogen atoms are repelled by the positive electrification, but not to the extent of disruption. As the axis of the molecule is involved in the electrification, and as there is slight cohesion, the molecule moves forward towards the negative pole, and the

movement is cataphoretic. At the point of neutralization of the currents the atoms of the molecule are dissociated, and oxygen immediately, by induction, seeks the pole to which its potential directs, hydrogen going in the opposite direction; or, if the current is not sufficiently strong to produce electrolysis, the water is heated as a whole. When the negative current enters the water electrification of the hydrogen part of the molecule takes place, but it is polar and does not involve the molecular axis. On the contrary, the greater bulk of the molecule is repelled. Therefore the molecule may maintain its position and the negative current may proceed by vibration to the point of neutralization. *Molecules of water not electrified will seek the negative pole by induction.* Consequently the cataphoretic action of the current on water is a flow towards the negative pole. It is important to note that the negative current evidently meets with a different degree of resistance from that met by the positive in passing through water.

62. Any substance held in solution, which because of its relative potential is not electrified directly, will seek the pole to which its potential leads. This occurs from the *inductive influence* of the current. The positive current will not electrify iodine in the presence of oxygen, owing to the more negative character and less atomic weight of oxygen. Therefore iodine by its potential, and through induction, seeks the positive pole, if the current is not sufficiently powerful to influence it by direct electrification. In the latter case iodine is carried from the positive pole, as in the case of spermatozoids (§ 237). Iodine is carried by induction from the negative pole, whilst most soluble salts because of their positive potentials are carried by in-

duction from the positive, the potential of salt being usually on the side of the base.

63. *Cataphoresis of Nascent Salts.* By placing a solution of any metallic salt on the positive electrode it will diffuse towards the negative. If there be employed a positive electrode of copper, zinc, silver, or an amalgam of mercury, there will be formed soluble salts by the oxygen, chlorine and other electro-negatives of the electrolyte combining with the metal of the electrode. The nascent salt is most frequently an oxychloride, but it is evident that iodides, bromides, and other salts under favorable conditions can be formed. A nascent salt thus formed is subject to the laws of cataphoresis and is carried toward the negative pole.

In the cataphoresis of nascent salts an electrolytic followed by a chemic action takes place, the latter being followed by cataphoresis. It is clear that any electro-positive substance, whether composing the positive electrode or merely placed at the positive pole, which is capable of forming a soluble salt with the electro-negative elements of the electrolyte, will be subjected to cataphoretic action by the current. Thus numerous metals other than those named, alkaloids, alkalies, and other electro-positives may be made to diffuse into an electrolyte.

64. The amount of cataphoretic work done has a direct relation to the amount of current used, but the character of the fluid on which the current acts—the amount of concurrent electrolytic work—has to be taken into account.

Kohlrausch discovered that atoms have distinctive rates of motion in a given liquid, independently of their combinations. Lodge gives the following table of the speed of atoms of the substances mentioned, the

potential being one volt per lineal centimeter of the electrolyte:

TABLE OF CATAPHORETIC SPEED OF ATOMS

Hydrogen	1.080 centimeters per hour.			
Potassium	0.205 centimeter per hour.			
Sodium	0.926	"	"	"
Lithium	0.94	"	"	"
Silver	0.166	"	"	"
Carbon	0.213	"	"	"
Iodine	0.216	"	"	"

The table is valuable in demonstrating the principle of atomic differential speed. The relative speed, however, will differ if elements of greater potential are present in the electrolyte. Thus with oxygen and iodine in the electrolyte the current would electrify oxygen to the extent of its capacity before charging the less negative and heavier iodine.

CHAPTER IV

Electrification by Induction

65. *Definition.* Electrification of a body at a distance from the seat of the electrifying force. Induction is electrification through the medium of polarized ether, a non-conductor intervening between the locations of the inducing and induced forces. It is the manifestation of an electrification by placing a conductor within the sphere of influence of an electric potential. A general definition is as follows:

Induction is a disturbance in the neutralization of the forces of a body by it being placed within the influence of a primary potential, the neutralization between the primary potential and surrounding forces being subject to reactions between the latter, all reactions taking place according to the inverse square of distance.

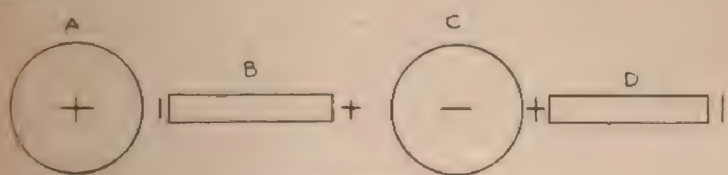


Fig. 14.
Electrification by Induction.

66. If an electrified body and a non-electrified conductor be approximated, but not brought into contact, the latter will take on electrification as follows: The

distal end will be electrified similarly to the primarily electrified body, and the proximate end will show opposite electrification. Thus in Fig. 14 A represents an electrified body, and B a body having the property of conduction. As the body, A, is electrified positively, the distal end of the conductor, B, will be also positively electrified, and the proximate end negatively. As A and B are not connected by a conductor, B is said to be electrified by *induction*. If B is removed to a distance from A the electrification of B immediately disappears. By the removal of B no force has been removed, and the force that induced the electrification of B still remains, the presence of B enabling the force to be manifested. What does the force act upon in the absence of the conductor, B? Our answer to this question is: That in the absence or presence of the conductor, B, the inducing force acts directly or indirectly upon the ether surrounding the electrified body, A, with the result of ether polarization subject to the law governing the reaction of forces. Let us consider: There are two bodies, one charged positively and the other negatively. Their potentials neutralize each other in inverse proportion to the square of the distance asunder. As the distance between the two bodies increases, that is, as the mutual neutralization of their forces decreases, reaction between the primary potentials and the potentialsof the proxima te bodies occurs, and this reaction has been termed induction. The following law may be formulated: *Induction increases in direct proportion to the square of the distance of the primary potentials, and in direct proportion as the reaction between the primary potentials decreases.* The primary or inductive potentials will act differentially on the forces of the material within the induced field according to the

law of the reaction of forces. It is evident that if polarizable ponderable matter is present in the induced field it will be polarized in preference to the ether. On the other hand if the ponderable material in the induced field possess slight molecular potentials and offer great resistance to molecular polarization (exmolecular neutralization) the ether may be polarized. Each molecule of ether or of ponderable matter will be acted upon and will react according to the law of forces. It is also evident that molecular potentials of ponderable matter will polarize the ether in the molecular vibratory or free spaces according to the same law, when ether is the only form of matter present. Furthermore it is evident that the difference between induced forces and primary forces is in the form of neutralization of the forces, and that induction is essential to the preservation of the equilibrium existing on the part of matter and force in relation to space, and is a manifestation of the neutralization of force, and is subject to the same law as reactions between primary potentials. The force of an electrified body is neutralized: (1) By a qualitatively opposed electrification created simultaneously with itself; (2) by the inductive potential of ponderable molecules; (3) by disturbing the immolecular neutralization of ponderable or ether molecules; the two latter being designated as induced because a previous neutralization has been disturbed by the primary force.

67. In Fig. 15 the surrounding ether is represented as polarized by the positive electrification of the insulated body, A. The positive atoms of ether being repelled and the negative atoms attracted. It is evident that if a body whose molecules vibrate freely—a conductor—is introduced within the area of polarization

the molecules of such a body will become polarized and will manifest themselves accordingly.

The electrification of the body, A, is an electric potential and the induced force or induced polarization is directly proportional to the amount of primary electrification. What is true of induction by electric potentials must be true of all potentials. Chemic potentials which are identical with electric potentials—both having the same fundamental units—*must* have induced forces, and each molecule must have its induced area—electric or magnetic field (§ 19).

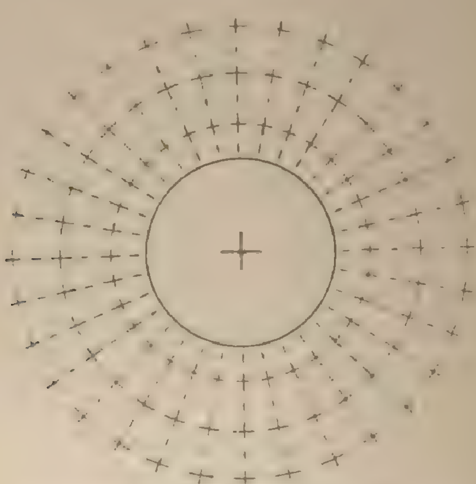


Fig. 15.
Polarization of Ether in the Induced Field.

68. The term *magnet* has been applied to certain bodies that attract iron. The natural magnet is a ferric oxide, Fe_3O_4, which has been magnetized through the inducing influences of the currents of the earth. Soft iron is quickly magnetized and demagnetized; whilst hard iron requires greater force, but retains its magnetization longer or permanently, the permanency de-

pending on molecular rigidity (§ 38) or fixed polarity.

69. If a magnet be divided, each part will be a complete magnet. If a body that is electrified by induction be divided, the *terminal parts* are found to be electrified, one positively and the other negatively, and the surfaces of the terminal bodies or parts, on removal from the electric field, are found to be equipotentially electrified. This demonstrates that ether is dissociated by induction and the atoms polarized at the terminals of the induced body. Without division of the body induced electrification disappears on removal from electric influence; magnetization may be more or less permanent. Magnetization and electrification are identical in that they depend upon the force of ether atoms as their ultimate units. Magnetization is the polarization of ponderable molecules, with polarized molecular ether in the molecular polar fields. In induced electrification the ponderable molecules are also polarized, but intermolecular ether is split up into its atoms, and the latter are polarized at the poles of the conductor. The poles of a magnet have no free ether atoms whilst the poles of an induced conductor have free ether atoms which are insulated and separated from each other when the conductor is divided (Figs. 87, 124).

70. When a conductor such as copper is placed within an electric or magnetic field the inductive force through ether polarizes the molecules of the copper, but produces no pronounced disturbance in the mutual relations of the ultimate units of the atoms (§ 22). When a magnetizable body such as iron is subjected to the influence of a magnetic or electric field, the molecules are polarized the same as in the other conductor, but with the remarkable additive manifestation of ultimate unit polarization. This is a *potential of*

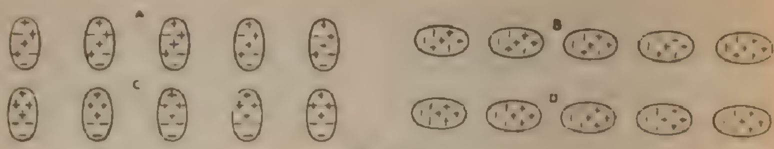


Fig. 16.

Representing copper and iron molecules, polarized and depolarized, showing potential of placement (§ 30): A, copper molecules depolarized; B, same polarized; C, iron molecules depolarized; D, same polarized.

placement based on the grouping of ultimate units, which, although neutralized immolecularly, are easily disturbed by exmolecular stimulus. It is clear that the introduction of a magnetizable body into an induced magnetic or electric field will be a re-enforcement of the energy of the field—the polarization of the ether of the field and the polarization of the magnet being in the same direction, the direction being governed by the character of the primary electrification, and the kinetic potential of the one being supported by the inherent although previously latent potential of the other. The expenditure of force is six times greater in the iron molecule in comparison to the copper molecule in electric conduction, but this property depends on the molecular vibratory balance. Forces which in a depolarized iron molecule are directed to the molecular equator in a polarized molecule are partially directed to the poles. It is possible that each atom of iron during magnetization acts as a molecule. The induced force therefore emerges from the magnet, re-enforced by the inherent potential based upon the distance between neutralizing ultimate units of the molecules of the magnet.

Iron is attracted by a magnet because of its inherent potential, and it is attracted to either pole of a magnet because of the property possessed by its molecules of

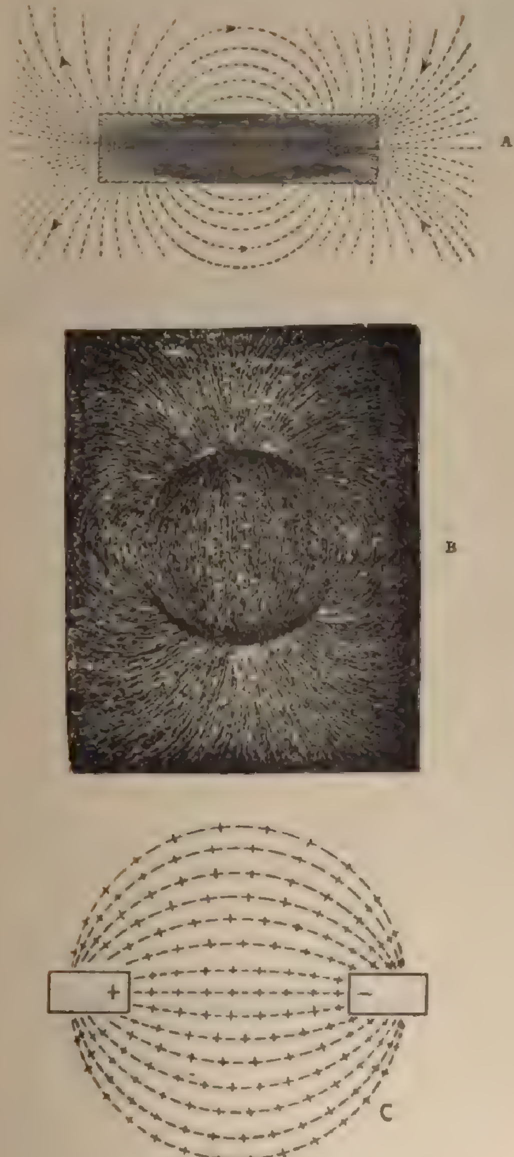


Fig. 17.
Indicating Differential Polarization.
See also Fig. 64.

changing their poles. This property depending on the relative movability of the ultimate units.

Fig. 17, A, B and C, represents the polarized ether or polarized particles in the polar electric or magnetic fields of a magnet or of an induced electrified body.

Fig. 18.
A, showing Induced Field of Electric Current (cross-section ; B, Revolutions of Ether around Current (longitudinal).

71. When a current is passing through a wire the ether surrounding the wire is polarized by the current. Fig. 18 represents the electric field or area of induced polarization of a current. Whether the ether in the electric field of a current is merely polarized, or whether there is a stream of positive ether in one direction and of negative ether in the opposite, depends on the intensity of the current.

72. A solenoid is a coiled conductor formed by winding copper wire over a cylinder, the wire forming part of a circuit. It is evident that the current on passing

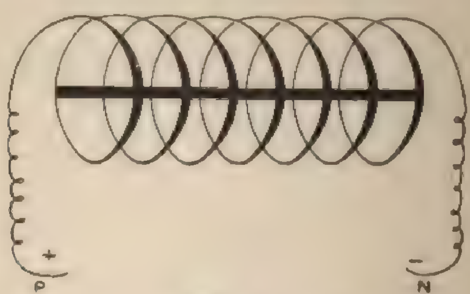


Fig. 19.
Representation of a Solenoid surrounding an Iron Core.

through the coils of a solenoid will produce an intense electric field, the ether being in a state of *stress* from the concentrated inducing forces of the coil; and that the field is still more intensified by the presence of an additional potential of magnetized iron.

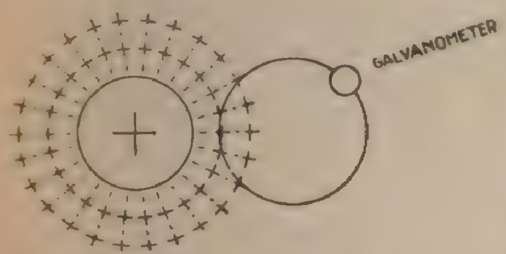


Fig. 20.

Showing electrified body and induced circuit within induced polarized field.

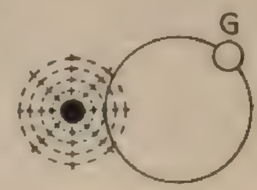


Fig. 21.

Showing induced polarized area of current with induced circuit (cross-section of primary circuit).

73. When part of a metallic circuit is placed within the area of ether-polarization, as in an electric or magnetic field, it is found that any modification of intensity in the field, or any modification of the relative position of the circuit to the polarized field, that takes place will be manifested in the circuit. Thus, if the polarized field is moved backward, the galvanometer needle will indicate a current in a certain direction. If, after the galvanometer needle is at rest, the field is moved forward the galvanometer will indicate a current in the opposite direction. The same manifestations will take place in the induced circuit as a result of changing the positive to negative electrification, or conversely; or of changing the direction of a primary current. As a result of these changes the galvanometer will show a true alternating current—a current that alternates between two potentials, a positive and a negative, each swing crossing the zero line (Fig. 22).

Fig. 22.
Representing Alternating Current.

74. If the electrified body is moved foward and then backward to the starting point quickly, or if the electrification is entirely cut off as in breaking the primary circuit, there will be a current in the induced coil vibrating between zero and a potential. Such a current is an interrupted current as shown in Fig. 23.

Fig. 23.
Representing Interrupted Current.

75. Rapidly interrupted or alternating currents cannot be measured by a galvanometer, because of the mechanical impossibility of the needle following the variations of the current.

The induced current is always in the opposite direction to the current that produced it, or the direction is such that it is opposed to the movement that produced it. The induced current neutralizes the primary current, the two currents being in passing equilibrium.

Faradic Apparatus

76. In the faradic battery the number of cells required is from two to six. These cells give the initiatory electro-motive force. The copper wire of the primary circuit is comparatively stout and short, so as to offer little resistance to the current. It forms a solenoid around the core.

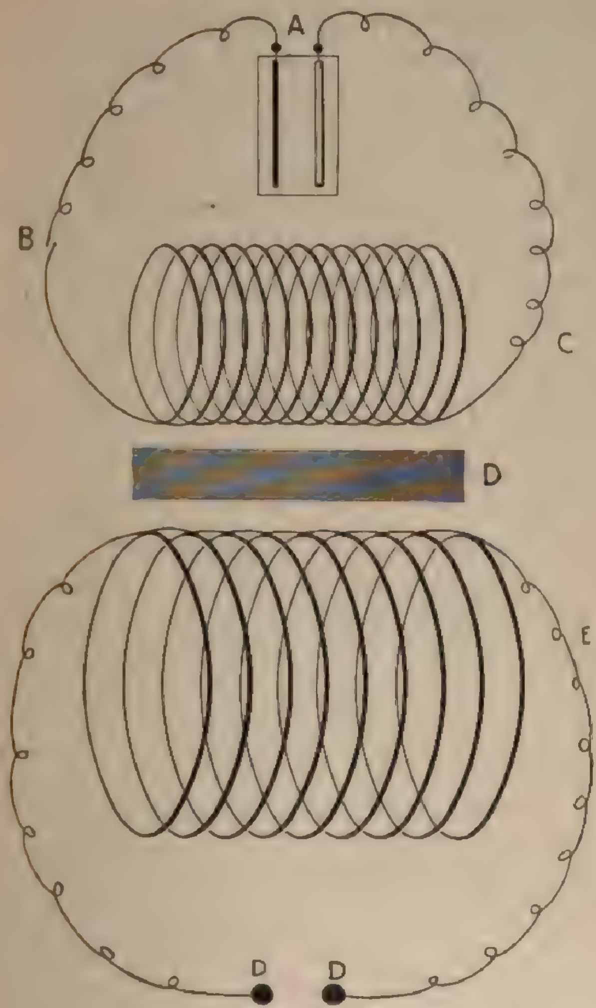


Fig. 24.

Faradic Battery: A, cells; B, make and break; C, primary coil which surrounds the core; D, core; E, secondary coil which is placed over primary coil; D, electrodes.

The core is composed of a piece of soft iron capable of rapid magnetization and demagnetization, and is for the purpose of creating an intense electric field. By its inherent potential the iron when polarized re-enforces

the primary current. The re-enforcement is by a potential of relative position of the qualitatively different units within the iron molecule—the positivities are more or less grouped together, likewise the negativities, immolecular neutralization (Fig. 14) taking place at relatively greater distances, hence a latent potential.

The secondary circuit consists of a comparatively thin, long wire with many turns in its coil. This coil is generally constructed so as to slide over the primary coil, its relative position to the electric field being thus capable of modification. Secondary coils vary in length from a few hundred feet to seven or eight thousand feet, and in thickness from No. 18 to No. 36 wire. Separate coils can be made of any length and thickness, giving the operator the choice of selecting and adjusting the one furnishing the desired current. A *continuous* coil is manufactured consisting of over 7,000 feet and tapped at different points, giving the choice of a number of sections, or combinations of sections, differing in thickness and length of wire, each furnishing a current of peculiar and distinguishable character.

77. The make and break is not only an essential part of a faradic apparatus, but it is a most important factor in determining the character of the current. The intensity, physiologic effect and therapeutic value of the current depend in a greater degree on its rate, smoothness and uniformity of its action than upon the character of any other part of the apparatus. Current breakers may be divided into two classes:

1. Those that are inserted within the primary circuit and derive their motive power from the primary current.

2. Those that are outside of the primary circuit

and have an independent battery force as their motive power.

The vibration of the first class depends on the attraction of the magnetized core, and the rebound of the spring during demagnetization.

The following description of a spring vibrator will sufficiently show the principle involved in all. In Fig. 25, the knob of the spring is within the magnetized

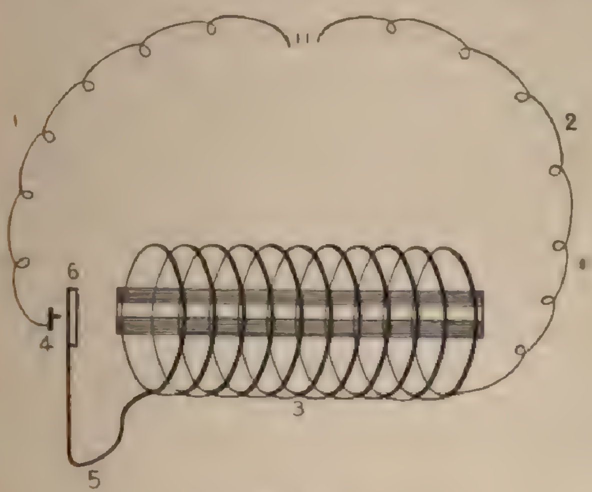


Fig. 25.

Spring Vibrator: 1 and 2 represent the conducting wires of the primary circuit; 3, core; 4, platinum point controlled by screw; 5, spring; 6, knob of soft iron on free end of spring.

field of the core, or that of a separate piece of iron, and one end of the conducting wire is continuous with the base of the spring, while the platinum screw is the terminal point of the other end of the conducting wire and is in contact with the spring when the latter is at rest, thus completing the circuit. When there is a current the coil is magnetized and attracts the knob on the free end of the spring, this movement of the spring

breaks the circuit at the platinum point, which stops the current and demagnetizes the core, and allows the spring to rebound and to make contact with the platinum point. The last movement closes the circuit and makes the current.

78. The possible frequencies of the vibrating rheotomes may be considered as about 10,000 per minute. They have the disadvantage of not being measurable by the operator. The best faradic instruments contain two interrupters giving slow and rapid breaks. In addition they may have a single impulse key that is controlled by the touch of the operator.

An interrupter having an independent motor force has advantages: Its rapidity can be modified without interfering with the electro-motive force in the primary circuit, and the frequencies can be increased and decreased at the will of the operator. He has also the means of knowing approximately the rapidity of the vibrations. This form of make and break is accomplished by a rotary intercalated in the primary circuit but driven by independent power. It interrupts the current two, four or more times every revolution. By such armature the vibrations may vary from one to fifty thousand per minute—the limit of obtaining differential physiologic results.

In some faradic batteries the mechanism is such that the primary or secondary currents can be selected—the secondary part of the apparatus can be shut off, and the patient brought within the primary circuit. This is a useless procedure, as the primary is merely an interrupted galvanic current which if needed for any purpose, such as muscle stimulation, can be better served by interrupting the galvanic current.

Faradic Current

79. The forces engaged in the production of a faradic current may be divided into those taking place during the *closed circuit*, and those taking place during the *open circuit;* these will be found to differ in the three main parts of the battery—primary circuit, the coil, and the secondary circuit.

During the make or closed circuit the current in the primary is distinctly galvanic in character, lessened in force by its setting in motion other forces—the magnetic and the contemporary part of the induced—and assisted by the inherent forces of the magnet. These merely hasten or retard the current and in no way change its character. The break of the primary circuit is instantly followed by the completion of neutralization of positive and negative ether in the circuit, part of the ether-current meeting in the coil and part backing toward the cell. Neutralization practically ends the closed period.

Depolarization is the distinctive act of the open or break period and is contemporaneous throughout the apparatus. By reciprocal induction depolarization is hastened in the individual parts. The co-operative feature of the depolarization and the absence of resistance, give a lightning-like character to the opening current. During the break all polarized molecules and all dissociated ether-units return to a condition of equilibrium or neutralization.

80. During the closed circuit the iron core is in the center of the polarized *stress*. Part of the energy of the current is spent in polarizing the iron molecules, but the potential energy of the iron molecule becoming active, the radiant force as it issues from the core is multiplied—is of greater intensity and capable of pro-

ducing a larger induced field. During the break of the current depolarization of the core and surrounding ether occurs.

81. The outer coil is embraced within the induced field, and through the polarized ether of the field molecular polarization of the wire is produced. Each molecule is surrounded by an area of polarized ether—free space—during rest (Fig. 26), which is differentiated in its polarization during action (Fig. 27). Part of the polarized ether is dissociated by the polarization of the molecule, and the positive ether atom is sent in one

Fig. 26.

Molecules of ponderable matter and fields of intermolecular polarized ether, representing wire of secondary coil during rest.

direction and the negative in the opposite, thus each *polarizable molecule is a means of tearing up ether*. The whole induced field of the primary current is in a condition of strain—every ether and ponderable molecule is polarized. As polarization is the first step to dissociation, as the pressure within the polarized field is intense, and as a way of escape is provided by means of the circuit, polarized ether is completely dissociated and the ether atoms seek reunion through the conductors as the path of least resistance.

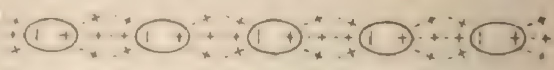


Fig. 27.

Polarized ponderable molecules and differentially polarized molecules of ether in the part of the secondary coil within the electric field during closed circuit.

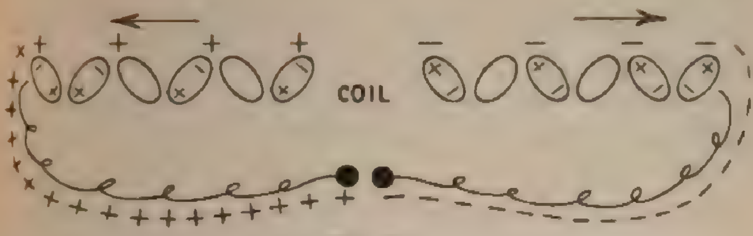


Fig. 28.

Molecules carrying the current by the trapeziform movement (§ 46) in the conductors leading from the coil, or part of coil, within the electric field, during closed circuit. The molecular induced fields are not shown.

During the closure of the circuit, the secondary coil by molecular polarization converts polarized ether into dissociated atoms—that is, the ether atoms are torn apart as in the galvanic cell. Moreover, as in the galvanic cell, the positive ether is sent along one conductor and the negative along the other, by which they are carried by the same trapeziform molecular movement. Therefore the *part of the coil within the electric field*, during the closed circuit, is similar to a galvanic battery.

During the open circuit molecular depolarization in the secondary circuit takes place, and the atomic ether neutralizes and returns to its intermolecular position.

82. The faradic is an interrupted current, not a true alternating current, that is, it vibrates between a potential and zero and not between two potentials.

The electro-motive force depends upon:

1. Galvanic cells—source of initiatory force.

2. Interrupter: Each time a ponderable molecule vibrates it splits up ether.

3. Core, where initiatory force is multiplied by potential of placement within the iron molecule.

4. The number of turns of wire in the secondary coil within the polarized area—pressure of ether atoms in line.

83. The induced current may be regulated by a modification of any of the above factors. If the first three are constant the electro-motive force in the secondary coil up to a maximum point will be directly proportional to the number of turns in the coil—the number of molecules in longitudinal extension that are polarized in the electric field. As each molecule is engaged in splitting up ether, the longer the longitudinal line the greater the pressure in front. Increasing the thickness of the wire increases the number of molecular carriers abreast and decreases the pressure.

84. The opening and closing currents in the secondary circuit differ in duration and character. The closing or current of polarization is twice the duration of the opening or depolarizing current. The depolarizing current gives a more intense spark, it has the same electric quantity but passes in a shorter time, and produces more intense physiologic action than the polarizing or closing current.

The closing current starts at zero, and the force has to overcome the molecular inertia and the mutual attraction of the ether atoms; the opening current has no such resistance. The first is the force that lifts a weight, the latter is the weight falling. The one is the potential collecting in the clouds, the other is the lightning.

85. *Tension and Quantity.* The so-called current of *tension* is produced from a long thin wire, having many windings and therefore large electro-motive force, the large number of vibrating molecules in longitudinal line making large pressure, but giving a current of small volume—a few vibratory carriers of ether abreast. It is analogous to water from a great height running through a small pipe.

It requires 4,000 feet of coil of No. 32 or 36 wire to glow a Geissler tube. With sufficient tension Roentgen rays are produced from the Crookes tube.

The current of tension has slight, or no power, in burning iron or steel, and it possesses in a less degree the properties required in electro-plating than the current of quantity or primary current. The possession of immense electro-motive force gives it the property of overcoming large resistances.

The term *quantity* has been used to designate a current produced from a comparatively short and thick wire—a few hundred yards of No. 18 or No. 22 wire—having few turns in the coil and consequently small electro-motive force. It possesses few polarized molecules in longitudinal line and therefore has small pressure. This current has large volume—a large number of ether carriers abreast moving slowly. Having small pressure there is slight power to overcome resistances. A current of quantity may be compared to water from a slight elevation running through a large pipe.

The current of quantity will not glow a Geissler tube but it will readily burn iron and steel. This current will electro-plate to a degree not attainable by currents of greater tension.

86. Currents of quantity and tension differ not only in their physical properties but also in their physiologic actions and therapeutic uses. It is evident that there are degrees of tension, and that between the extremes of the highest tension currents, and lowest tension or quantity currents that produce differential physical or physiologic results, there are currents of modified tension peculiarly adapted for certain therapeutic purposes.

As the opening or depolarizing current produces

more pronounced effect it determines the polarity. The cathode can be recognized by its greater effect on sensory or motor nerves, the difference between the positive and negative poles being more marked with short coils and with small resistances.

87. *Regulation of Current.* When the helix of the secondary circuit is movable, as it slides over the primary coil a greater number of turns of the coil are brought within the electric field, thus increasing the intensity of the induced current.

If there be placed within the circuit, but outside of the electric field, a coil of wire, the resistance will increase the more the coil is brought within the circuit. As this coil is gradually eliminated from the circuit the resistance is decreased and the current increased.

By sliding a copper shield over the core, the latter is protected from the action of the primary current, thus decreasing the intensity of the induced field and decreasing the induced current.

The primary current is decreased by sliding the secondary coil over the primary, the reverse induction of the secondary coil retarding the flow of the primary current. The approximation of polarizable material to the primary current or its intercalation between potentials creates an induced force opposed to the primary. In the absence of polarizable material the positive potential in part of the circuit reacts on negative potential in the opposite part with an increased electro-motive force. The principle is the same as specific inductive capacity, and is a manifestation of forces being neutralized inversely as the square of distance.

Various rheostats can be used for the purpose of modifying the currents. The current can be modified by changing the length or thickness of the wire in the

induced helix. This is mainly a question of tension if the primary electro-motive force and coil resistance is proportionally constant.

88. *Direction of the Current.* Figs. 29 and 30 show the directions of the primary and secondary currents during closed and open periods.

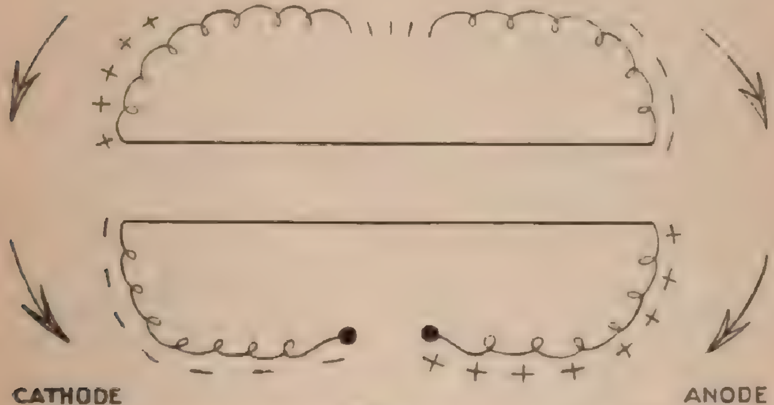


Fig. 29.
Primary and Secondary Currents During Closed Period.

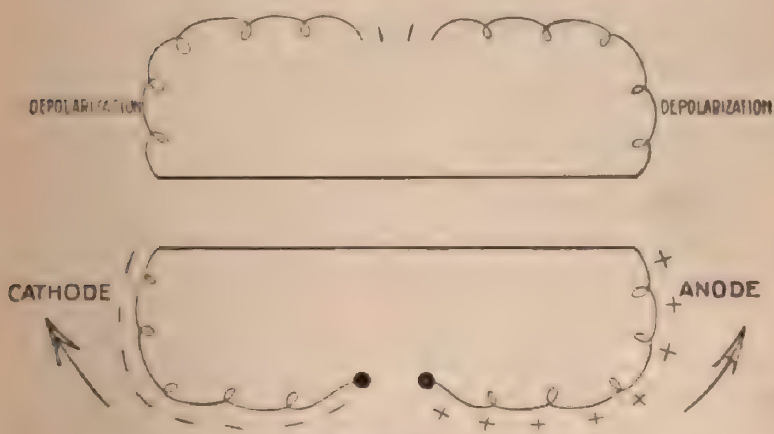


Fig. 30.
Primary and Secondary Currents During Open Period.

89. Although the electro-motive force can be multiplied in the secondary circuit almost indefinitely, the energy is only seventy-five per cent of that of the primary current. The energy is obtained by multiplying the electro-motive force by the current, the latter being comparatively small in induced circuits.

90. Every electro-therapeutist should be able to test his own battery for tension, for smoothness and for rapidity of vibration. With 4,500 feet of coil in the secondary circuit and with sufficient initiatory force —two to six cells—the characteristic luminous effects of the Geissler tube ought to be produced. If the action of the vibrator is uneven it will be at once apparent in the irregular motion of the discs within the tube.

A sufficiently delicate test is obtained by placing the fingers on the metallic part of a bipolar electrode, when irregular vibrations or harshness of current will be evident to the touch.

The value of a faradic battery as a therapeutic agent resides in the smoothness, regularity and high frequencies of its vibrations, and on its furnishing a variety of degrees of tension. The combination of a suitable tension with a degree of frequency of vibration, as indicated by the therapeutic requirements, will be only attained by using judgment founded upon a proper knowledge of the physical and physiologic actions of faradization.

CHAPTER V

Static Electricity

(Franklinic Currents)

91. Static electricity—electricity at rest—in equilibrium—is the electrification of a body insulated and therefore apart from all disturbing electric influences. It is the placement of ether atoms on ponderable molecules surrounded by non-conducting molecules (§ 5).

Electro-static machines have two principles in their construction—friction, and induction or influence.

Frictional Machines. Frictional machines are not much in use at the present time, but as they represent both principles they will be described in this work.

In Fig. 31, the parts of a frictional machine are represented as follows: A, revolving plate of glass; B, a rubber—leather and amalgam of tin and mercury; E, metal comb; C and F, conducting wires attached to rubber and comb; G and D, electrodes. The rubber is in contact with the glass so as to rub slightly. The comb is not in contact with, but approximates the glass. When the glass plate revolves friction takes place with the rubber, resulting in the glass being positively electrified, and the rubber negatively (§ 3). As the rubber and connecting metallic wire are conductors, the negative electricity will spread over their surfaces so as to establish an equipotential surface and will

therefore appear at the electrode as a negative charge (§ 8).

The electrification on the glass at the point of friction confines itself to that part, because it is surrounded by a non-conductor—the glass itself. The revolution of the glass, however, brings the positively electrified part towards the comb, which as the charge approaches

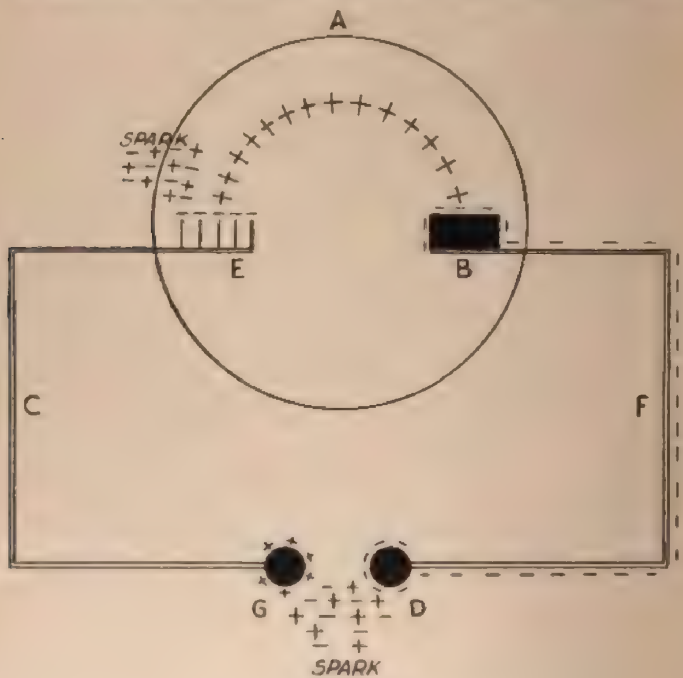


Fig. 31.
Frictional Static Machine.

becomes inductively electrified—inductively because the comb is not in contact with the glass. The comb, the metallic wire, and the electrode, G, being conductors and one electric body, that is in contact, the positive charge will appear at the distant or electrode end, G, and the negative charge at the proximate end, E (§ 66).

It will be seen that at electrode, G, there is positive electricity, and at electrode, D, negative electricity, and that the glass and comb are also oppositely electrified. These opposite electrifications neutralize through the dielectric medium, air.

The union of the positive and negative ether atoms through the air between the comb and the glass and between the two electrodes is accomplished as follows: The particles of air adjoining the charged terminals become electrified, but the air not being a conductor its electrified particles are carried towards each other, causing a spark. The positive and negative atoms of ether become molecular, and the union manifests itself in light or heat phenomena (§ 126).

92. *Influence Machines.* The student of electricity will easily understand the working of influence machines if he has mastered the fundamental principles and facts of induction and insulation.

Whatever the mechanical construction of those numerous machines they all inductively split up the ether molecule so that the two electrodes are charged respectively by positive and negative ether. The description of one machine will sufficiently illustrate the principles of all.

The Wimshurst influence machine (Fig. 32) has two circular glass discs, A and B, ⅛ inch apart and rotated in opposite directions. On the outer surface of each are a number of metal sectors equi-distant apart. Across the diameter of each plate is fixed a metal rod, E and F, at the ends of these are fine wire brushes so situated that each sector and the one diametrically opposed are metallically connected twice every revolution—the sectors just touching the tips of the brushes as they pass. The electrodes are connected with forks

furnished with combs, D and C. The forks embrace the glass plates at their horizontal diameter, so that each sector approximates a comb on each fork every revolution. The term collector has been applied to the combs, but this is a misapplication, as the combs do not collect electricity but are inductively electrified. If dry the machine is self-exciting. The parts of the

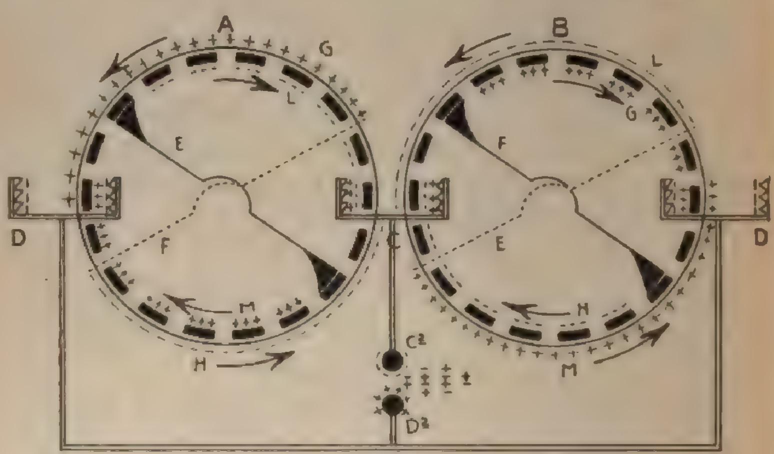


Fig. 32.
Influence Machine.

machine as represented in Fig. 32 are as follows: A, indicates front view of front plate; B, back view of back plate; C, C', fork and metallic combs united by conductors with brass ball or electrode; D, D', same as C, on opposite circumference of plates, and are shown as double; E, fixed conductor with metallic brush at each end touching diametrically opposite sectors as they pass on plate, A, shown on the background of plate, B; F, the same on plate, B; G and H, on plate, A, represent charges on sectors of plate, B, and are also marked on the sectors of B; L and M, on plate B, represent charges on plate A, and are also marked on the sectors of plate

A. The charges are marked on the background for the purpose of showing their direction. When the page is folded backwards on a line from C to D[2] the various parts of the figure will be in the relative position of the parts of the apparatus which they represent.

93. When a non-electrified conductor is placed within the polarized field of an electrified body but separated from it by non-conducting material, the conductor becomes electrified by induction (§ 65, 66). By this law the sectors on the glass plates are reciprocally inductively electrified as they pass each other. When the inductively electrified sector is metallically connected with the diametrically opposite sector by means of the metal rod, the sectors and the rod become one electric body, and the induced charge will appear at both ends of the electric body according to the repulsion and attraction of the inducing agent. If one of the upper sectors on the back plate, B, be charged by positive electrification the opposite sector on the front plate, A, will immediately be charged by induction. When the induced sector is touched by the metal brush this sector will be charged negatively and the one touched by the other brush will be charged positively. These sectors, with their charges, immediately move on, and when opposite the sectors on the back plate, B, on which the brushes rest, the latter will be reversely charged, and will also move on with their charges, and in turn induce the electrification of the sectors on the front plate. When an electrified sector approaches a comb the electric conducting body—comb, fork, wire, and electrode—receives an induced charge, opposite electrifications appearing at the comb and electrode. It will be seen from an examination of the plates, A and B, that the sectors on both plates approaching fork C

are charged negatively, and those approaching fork D are charged positively.

The charges on the combs being of opposite character to the sector charges which induce them, and opposite to each other, it follows that the electrodes will be also oppositely charged. It will be seen that a sector becomes inductively charged when it is in contact with the metallic brush, that it carries the charge forward and inductively charges a sector on the other plate, and when passing the comb becomes neutral. The combs and the sectors being separated by a dielectric medium neutralization takes place with a spark. The electrodes being the distant ends of the electro-conducting bodies of which the combs are the proximate ends, will have an increasing amount of free atomic ether accumulating on their surfaces; positive on the one, negative on the other. When the difference of potential is such as to overcome the resistance of the dielectric medium, air-sparks will take place announcing the consummation of union. When two sectors are connected by means of the rod and brushes and are thus one electric body which is inductively charged, the sectors immediately move on with their charges. It has been stated (§ 69) that when an induced electric body is divided, the terminal parts retain their respective charges, which become primary. This is exactly what takes place in the case of the sectors. It will be observed that the term primary is used to denote a body with a single charge, which is kept in position by insulation, whereas a body charged by induction has differential terminal charges kept apart by inductive influence.

The principles upon which force is transformed in the Wimshurst influence machine may be formulated as follows:

1. When an induced electrified body is divided and removed from the inducing influence its terminal potentials become primary, one division of the body being positively charged and the other negatively. This division occurs when sectors pass from under the brushes.

2. The newly created primary potentials inductively charge other bodies. This induction takes place when the charged sectors approximate sectors in contact with the brushes of the opposite plate.

3. When an induced electrified body has a terminal charge neutralized by the opposite charge of a different body, the first body becomes primarily charged, and this charge will neutralize in the direction of least resistance. This series of events takes place when neutralization occurs at the fork, leaving the electrode with an opposite potential, which accumulates to the point of rupture.

94. Electro-static machines have very high electromotive force—calculated to be sixty thousand volts per centimeter of spark length—and slight volume—five thousandth of a milliampere per quarter inch spark. The volume per spark length varies with the number of plates. The voltage varies with the diameter of the plates.

The electro-motive force is in direct proportion to the amount of molecular ether separated into ether atoms. The latter depends directly on the number of times that induction takes place, which in turn is influenced by the number of revolutions. The diameter of the discs therefore can only affect the electro-motor force through the revolutionary speed. Notwithstanding we speak of these machines as static there are currents in their various parts, as for instance the sparks at the

electrodes and combs are currents, and there are also currents of induction in the conductors. These cur-

Fig. 33.
Static Machine.

rents have volume—the number of ether atoms that pass one point at a given moment. The number of ether atoms set free at the electrodes will be increased

by multiplying the number of plates. Therefore the volume is proportional to the number of the latter. The spark current differs from both galvanic and induced. It is a real ray of energized matter. The particles of air around individual electrodes become electrified and fly toward each other with the result of neutralization. The crackling sound no doubt is caused by the particles rushing through the intervening atmosphere, but the light is produced after neutralization takes place. It is an interrupted current because the inductions throughout the machine are necessarily interrupted. Furthermore it is doubtful whether a continuous current could be obtained with a spark, as the displacement of energized matter by other particles must have more or less interruptions.

Notwithstanding the electric display in this current amperage is insignificant. The difference of potential on the other hand is immense, but this embraces the atomic ether of the whole machine which has to overcome resistances made more distinct by interruptions.

The static machine has increased immensely in therapeutic value and has been popularized by its usefulness in producing the Roentgen ray (§ 130). The choice of a machine depends upon the character of the intended work. Roentgen ray work requires very high pressure—electro-motive force—many revolutions, and plates of large diameter in order to steady the current.

The Spark

95. The spark has been called by Faraday a disruptive discharge. In the broadest sense it is the result of electricity travelling through and neutralizing in a dielectric medium.

The spark is oscillatory in character, and has not the steady and continuous character of the galvanic current. It varies with the length, the density, and character of the dielectric medium, and with the electro-static pressure existing in the conductors. The spark also depends on the size of the conducting surface; the larger the surface the less electro-motive force is needed to produce a given length of spark.

When electrodes of different sizes are used, the spark is longer when the smaller one is made positive than when it is negative (§ 23). This is a remarkable fact, and has been utilized by Gangian in the construction of electric valves, the electric flow being readily transmitted in one direction whilst obstructed in the other. It is found also that a small ball electrode gives a longer spark when charged by induction than when charged directly.

Rarefaction of the gaseous medium lessens the resistance and increases the length of the spark. The decrease of resistance with lessened density takes place to a minimum value, when it again increases, so that in a high vacuum great pressure is required to produce a spark. Changing the nature of the gaseous medium modifies the length of spark. Faraday arranged the following gases in the order of their resistances: Hydrogen chloride, air, carbon dioxide, nitrogen, oxygen, illuminating gas, hydrogen.

96. *Spark Characteristics.* Various conditions modify the disruptive discharge. Faraday classifies sparks as follows: 1, the spark discharge; 2, the brush-discharge; 3, the glow-discharge; and 4, the dark-discharge.

The *spark-discharge* is a brilliant line of light, straight when the dielectric is not thick, but irregular when the distance is increased. Through air at ordinary pressure

it is nearly white, becoming bluish as it is lengthened. In rarefied air it is reddish purple, and different gases give characteristic colors.

The *brush-discharge* can be seen by lengthening the distance between the electrodes. The spark throws off fine ramifications in the direction of the cathode, which finally take the form of a brush or tuft with a single stem from the positive, and which does not quite reach the negative electrode. In air the brush is purple and is accompanied with a dull snap. It is intermittent and gives a musical note.

Fig. 34.
Spark.

The *glow-discharge* is obtained by reducing the areas of the electrodes, increasing the pressure, or diminishing the resistance as by decreasing the air pressure. It appears like a phosphorescent lambent flame. It produces no sound and apparently is not intermittent. Under ordinary air pressure a positive glow is more readily produced, although in rarefied air a negative glow is easily obtained. Currents of air can be detected accompanying this form of spark.

The *dark discharge* is obtained by diminishing the size of the electrodes and increasing the distance between them. A glow is observed on the negative terminal, whilst the positive and the intervening space remains dark, a purple discharge on the positive electrode is seen when the distance is further increased, the intervening space between it and the negative glow remaining dark.

97. The spark is capable of effecting chemic changes. A peculiar odor is perceived, due to ozone. About 15 per cent of the oxygen present may be converted into the synthetic modification.

98. *Action of the Spark-Current on Electrodes.* The spectroscope has shown that particles of cadmium, antimony, bismuth, lead, tin, iron, zinc, and copper, when these substances form electrodes, are detached and carried along by the current. The substance imparts a peculiar color to the electric discharge, combined with distinctive colors belonging to oxygen, nitrogen, etc., of the medium. Aluminum and magnesium are detached with the greatest difficulty. In rarefied hydrogen the spark is crimson; oxygen gives a greenish white, carbon dioxide a green, nitrogen a purplish red, and fluoride of silicon a blue.

99. When positive and negative electric charges are separated by a dielectric medium, the property of attraction existing between the two charges tends to disrupt the medium. The insulating character of the dielectric prohibiting union by means of vibratory conduction, the electro-positive elements in the medium, such as hydrogen and carbon, are attracted to the negative pole, and the electro-negative elements, such as oxygen, are attracted to the positive. These molecules become electrified and fly towards each other. When

they meet the positive and negative atoms of ether form molecular ether, and at the point of neutralization light is manifested. The dark part of the medium is where the electrified particles are moving without meeting the opposite current.

On the surface of the electrodes molecules are electrified. In air, as there is no cohesion to overcome, the particles form a real ray of energized matter, but they produce the light where they strike the opposite current (§ 69, § 126).

A study of the facts connected with the electric spark leads us to believe that there is an inherent property in negative ether tending towards diffusibility which is absent in positive ether (§ 23). The possession of such a property explains why a large negative electrode decreases the resistance beyond the measure of decrease when the same electrode is positive (§ 167).

CHAPTER VI

Sinusoidal Current Apparatus

100. This apparatus produces an alternating current of a special character. It takes its name from the fact that in its relation to time it follows the law of sines. Graphically it produces a sinuous curve less abrupt than that of the ordinary faradic apparatus (Fig. 35).

A sinusoidal machine is represented in Fig. 36, and the following description of it is given by Rockwell: "The alternator on the top of the table to the right is driven by a small motor running on the Edison direct 120-volt current (shown on left). The field frame is of laminated iron supported by castings, and has twelve poles. On each pole is a spool with two windings of wire. The inner has eight layers of fine wire, and the outer two layers of coarse.

"All the fine wire windings are connected in one series, which constitutes the secondary or delivery coil. All the coarse wire windings are connected in another series, forming the primary or field winding of the machine. By this arrangement it is only necessary to drive the armature, which is a combination of laminated iron discs, to transform the continuous primary current into alternating current waves in the secondary circuit, and by duly proportioning the grooves and projections on the armature surface, these waves are made sinusoidal.

"Twenty-four alternations or twelve complete perio
are generated for every revolution of the armature, a
since a speed of 4,800 revolutions per minute can
attained, the frequency can be carried to 1,920 altern
tions per second, or over 115,000 alternations p

Fig. 36.
Sinusoidal Apparatus.

minute. For steady running a more moderate spee
and frequency will usually be desirable.

"The primary winding of the alternator is excited b
the 120-volt direct current, which is controlled by
lamp rheostat, the switchboard operating it being show

in the front of cut on the right and the lamps being placed under the table. In this way the strength of the secondary currents can be controlled independently of the frequency.

"The speed of the motor, and consequently the number of alternations of the secondary currents, can be varied by the lamp rheostat shown in the front of cut on the left, as this rheostat is included in the motor circuit.

"The rheostat shown in the center of the table is connected in shunt with the secondary circuit, and is used to vary the strength of the current applied to the patient."

Condensers

101. When two insulated metallic discs are separated by a dielectric medium such as air, glass, spermaceti, resin, pitch, wax, shellac, sulphur, etc., and are charged, it is found that they have an electro-motive force according to their distance apart, and according to the material of the medium.

The term *capacity* has been used to denote the quantity of electricity necessary to charge the plates to a unit difference of potential. The plates or system of plates have been termed *condensers*. The quality of modifying the potential between two bodies, their charges remaining the same, possessed by certain dielectric substances, was termed by Faraday, *specific inductive capacity*, and by Maxwell, *dielectric constant*. It differs according to the dielectric and is therefore a property of the medium itself. Specific inductive capacity is inversely proportional to the neutralizing capacity of the media. The neutralizing power of an

element rests on the strength and freedom of the inductive potential of its molecules—it rests on the differential distance between neutralizing units. Material whose molecules have slight inductive potential or whose molecular poles are strongly fixed has a large dielectric constant. It is obvious that forces react in inverse proportion to the square of distance only with constant media, and that a change of medium modifies the reaction between primary forces simply by neutralizing their potentials or resisting conduction. Forces act on media by a disturbance in the neutralization between immolecular units, or a disturbance in the neutralization between the units of a molecule and an extrinsic force.

TABLE OF DIELECTRIC CONSTANTS

Substance.	*Dielectric constant.*	*Observer.*
Beeswax	3.67	Cavendish.
Shellac	2.00	Faraday.
Resin	2.48	Boltzmann.
Paraffin	1.96	Wullner.
Flint glass, extra dense	10.10	Hopkinson.
Sulphur	2.58	Gordon.
Ebonite	2.284	Gordon.
Carbon disulphide	1.81	Gordon.
Turpentine	2.15	Silow.
Hydrogen	0.999674	Boltzmann.
Carbon dioxide	1.000356	Boltzmann.
Carbon dioxide	1.0008	Ayrton & Perry.

102. The most common type of condensers is the Leyden jar. It is simply a glass jar covered inside

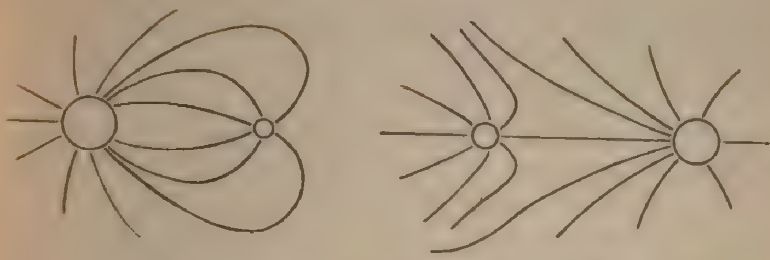


Fig. 37.

A shows lines of force between two bodies differing in the quality and quantity of their electrifications; B, two bodies having electric potentials of the same quality but differing in quantity, the lines of force showing distortion, and impenetrability of an induced to a like force. (*Copied from Maxwell.*)

and outside with tin foil (Figs 38, 39). On the top of the jar is a brass knob in metallic connection with the tin foil on the inside but insulated from the foil on the outside. When the inside foil is electrically charged, the outside becomes oppositely charged, if it

Fig. 38.

Leyden Jars Joined in "Parallel Arc."

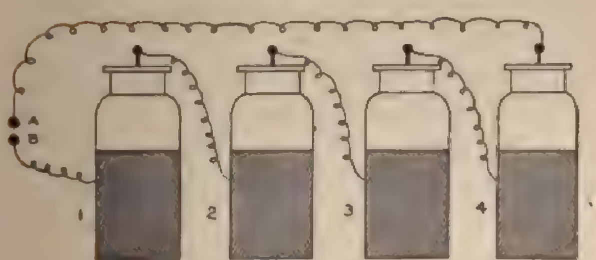


Fig. 39.

Leyden Jars Arranged in Series, or in "Cascade."

is not insulated. The outside charge comes from the earth or proximate bodies.

It must be remembered that equal quantities of positive and negative electricity are always produced by the dissociation of the ether molecule. When a Leyden jar is charged inside positively the negative concomitant approaches the positive as nearly as possible and consequently charges the outside foil. The outside charge is not by induction but by direct negative electrification. The submarine cable is an elongated Leyden jar, the wire which is insulated is directly charged and the outside—water—takes on opposite electrification.

THERMO-ELECTRICITY

103. The phenomena of reciprocal transformation between heat and electricity is evidenced by placing different metals in a circuit, the junctions of the metals having different temperatures.

Let two metals be bent and united as in Fig. 40, and let the junction, A, be heated, and the junction, B, kept cool; if a galvanometer be placed within the circuit a current will manifest itself. The difference of temperature creates a difference of thermal potential. The heat under ordinary circumstances would merely diffuse itself, as there is a tendency to establish an equilibrium of temperature, through thermal conductivity, but under the conditions named the ether in which heat is manifested will be split up, its positive element seeking the point of low potential in one direction, and the negative going in the opposite (Fig. 40), thus forming an electric current.

The metal through which the positive ether flows has been said to be thermo-electrically negative to the one

through which travels the negative current, and the latter is thermo-electrically positive to the former (§ 37). However the two states are relative in degree, and accordingly changeable in any one metal.

Two metals united in this way are called a thermo-electric cell and the current so produced a thermo-electric current. The electro-motive force depends on the difference of temperature of the junctions, mean temperature, and kind of metal. By multiplying the cells batteries are constructed called thermopiles, or thermo-electric batteries, bismuth thermo-electrically positive and antimony thermo-electrically negative being used in their construction.

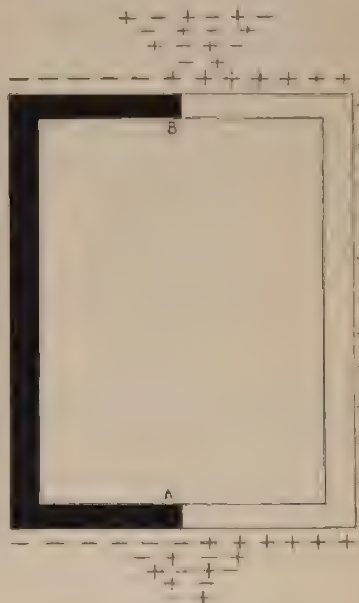


Fig. 40.
Thermo-Electric Cell.

Thermo-electricity illustrates the reciprocal transmutation existing between heat and electricity. In Fig. 40, at the junction, A, is a thermic potential—molecular ether existing as heat—which the difference in thermic potential of the junctions makes into a heat current but which the difference in the electro-chemic potential of the metals splits up into an electric current—ether atoms. At the junction, B, the ether atoms unite to form molecular ether radiating as heat.

The following table gives the relative position of

certain metals in thermo-electric power, with lead as zero:

Bismuth	+	Platinum	—
Cobalt	+	Copper pure	—
German silver	+	Antimony	—
Mercury	+	Iron	—
Lead	0	Tellurium	—

All of the elements named are specifically electro-positive. If the table included all elementary substances an equatorial element such as carbon would be zero.

Electric Units

104. Newton's first law is stated thus: The unit force is that force which, acting for a unit of time, on a unit mass, produces a unit velocity. A unit of force therefore depends on the units of length, mass, and time. According to the absolute system, the unit force is that force which acting on a mass of one gramme, for a second of time, produces a velocity of one centimeter per second. This force is called one dyne.

A unit quantity of electricity is that amount which exerts on an equal quantity, placed one centimeter from it, the force of one dyne.

The practical units of current, of electro-motive force, and of resistance are founded on the absolute units, or on the C. G. S.—centimeter, gramme, second—system, and are now universally employed in the measurement of electric quantities. The electro-magnetic system of units, together with their relations to the C. G. S. system, is tabulated as follows:

ELECTRO-MAGNETIC SYSTEM

Name of unit.	*Equivalent in C. G. S. units.*
Current—Ampere	$\frac{1}{10}$
Electro-motive force—Volt	100,000,000
Resistance—Ohm	1,000,000,000
Quantity—Coulomb	$\frac{1}{10}$
Capacity—Farad	$\frac{1}{1,000,000,000}$

For convenience these units are subdivided, and in medical electricity the milliampere is adopted as the unit of current force.

Electric Quantity. The term coulomb denotes the quantity of electricity which passes any cross-sectional area, in a second of time, when the current measures one ampere.

Any one of the quantities, ampere, volt, and ohm, is deducible when the other two are given. Ohm's law is expressed in absolute quantities thus:

$$\frac{\text{Current}}{\text{One ampere}} = \frac{\text{Emf—one volt}}{\text{Resistance—one ohm}}$$

The unit of work or energy is called a "Watt," and is equal to 1/746 horse power. Electric energy is the product of the current and the electro-motive force. One ampere flowing under a pressure of one volt gives out energy of one Watt.

Galvanometer

105. If a suspended magnet be placed near a circuit in which there is a current flowing, there is a

tendency on the part of the magnet to assume a position at right angles to the current.

The law governing the action of the magnet may be stated thus: The deflection is in direct proportion to the strength of the current and to the proximity of the current and magnet. By having the magnet and circuit made relatively immovable the law is reduced to its first factor: The deflection of the needle is directly proportional to the strength of the current.

It is clear that on this principle an instrument can be constructed to measure the strength of the current; the galvanometer or milliamperemeter is such an instrument. For the purpose of intensifying the current at the situation of the magnetic needle, many turns of wire are made to encircle it, as in a solenoid.

The needle is provided with a dial and pointer. The pointer represents the half of the needle, and is usually deflected towards the positive pole of the current. The magnetized needle in the absence of the current is influenced by a magnet so situated as to keep it parallel to the circuit wire, which is the zero point. The deflection of the needle therefore represents the difference between the power of the directing magnet and of the current over the needle. In stationary galvanometers the earth can be used as the directing magnet.

As the scientific application of the constant current depends largely on its correct measurement, the reliability of the meter is important. The operator should know how many current-units he administers, which he cannot do if the instrument has a standard of its own.

If we assume that the ether in immediate proximity to the current is polarized (§ 66, § 73) and imparts corresponding polarization to all polarizable objects, we

will have a rational explanation of the action of the needle. This explains a condition which has been designated "stress," an unscientific term.

In Fig. 41, A represents cross sectional areas of circuit and induced polarized field of current, with needle within its area. B, C, and D represent position of circuit, magnet and needle when there is no current. Whether the ether surrounding the current is merely polarized, or whether there is an ether current or whirl—the positive ether rushing in one direction and the negative in the other—cannot be decided. There is nothing in the character of the ether to prohibit such

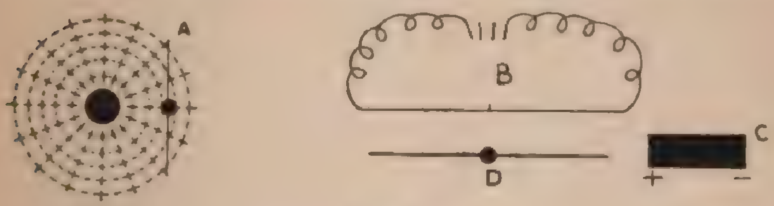


Fig. 41.
Diagram of Galvanometer.

a double stream, and it is probable that with an intense current that it exists. The same force that polarizes the needle also polarizes the ether, the positive ether and the positive end of the needle therefore are directed similarly; both are acted on by the inductive force of the current. The needle is in a position of a dielectric medium between potentials in the circuit.

When we stand facing a current with the positive to our left and negative to our right the positive pole of the needle will tend upwards and the negative downwards. For convenience in measuring currents the unit employed in reading the dial is one milliampere, ten milliamperes, or one hundred milliamperes; this is

accomplished by measuring the whole current, one tenth of the current, or one hundredth of the current, the part not measured being diverted by means of a shunt (Fig. 42).

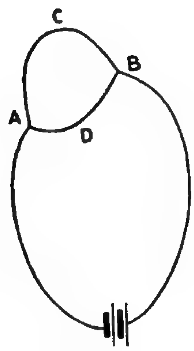


Fig. 42.
Shunt.

If a circuit divides into branches as shown in Fig. 42, the current divides also. Any branch of a circuit serving as a by-pass to another branch is termed a shunt. The amount of current passing through one branch, A D B, will have a relation to that passing through the other branch, A C B, inversely proportional to the relation of the resistances of the paths (§ 17).

CHAPTER VII

BATTERIES

106. *Tabulation of Cells.*

Name.	Electro-positive plate.	Electro-negative solution.	Neutralizer of cations, or outposts of electro-negative plate.	The relatively electro-negative plate.	Volts.
Volta	Zinc	H_2SO_4	None	Copper	1.0 to 0.5
Smee	Zinc	H_2SO_4	None	Platinized silver	1.0 to 0.5
Law	Zinc	H_2SO_4	None	Carbon	1.0 to 0.5
Grove	Zinc	H_2SO_4	HNO_3	Platinum	1.9
Bunsen	Zinc	H_2SO_4	HNO_3	Carbon	1.9
Leclanché	Zinc	$NH_4\,Cl$	MnO_2	Carbon	1.4
Papst	Iron	Fe_2Cl_6	$Fe\,Cl_6$	Carbon	0.4
Daniell	Zinc	$Zn\,SO_4$	$Cu\,SO_4$	Copper	1.07
De la Rue	Zinc	$Zn\,Cl_2$	$Ag\,Cl$	Silver	1.42
Weston	Cadmium	$Cd\,SO_4$	Hg_2SO_4	Mercury	1.25
Plante / Faure	Pb			$Pb\,O_2$	2.1 to 1.85

107. *Chemic Potential.* The foregoing tabulation shows that the zinc is the favorite electro-positive plate, for the reason that it has sufficient positive potential combined with solidity to make it practically superior. The alkali metals are superior to zinc in the intensity of their affinities, but the lack of stability makes them unavailable.

Theoretically any electro-positive, when in contact with an electro-negative, has the essential potential for producing the chemic action and setting free ether which is convertible to an electric current. The

electro-negative solution has a molecular potential of free negative units. The greater the negative potential or negative stored energy there is in the molecule the more suitable it is for the electro-negative solution. The table shows that nearly all of the elements in the solutions contain large quantities of oxygen or chlorine, combined with other negatives such as sulphur, and elements with slight positivities such as hydrogen. The Daniell and De la Rue batteries are apparently exceptions, and will need further explanation.

108. *Polarization.* When chemic action takes place in the battery there are set free positive elements such as hydrogen, which by induction seek the negative plate. Moreover, electrolysis occurs within the cell, and the newly formed salts such as zinc sulphate are again decomposed, and the positive ions are deposited on the negative plate. Obviously this will make the negative equally positive with the positive plate and destroy the difference of potential.

Neutralization of Cations. The polarization of the electro-positive ions is prevented by guarding the negative plate by a substance with a large negative potential. Substances containing large quantities of oxygen or chlorine are therefore placed in position to intercept the positive ions as they seek the negative plate. Thus free hydrogen unites with the oxygen of nitric acid, the latter being reduced, and the hydrogen being rendered harmless, more stable compounds resulting.

109. *Electro-negative Plate.* The material for the electro-negative plate is selected because of its having a less positive potential than the positive plate. The copper atom has a smaller number of positive units and has a less positive potential than the zinc atom, nevertheless copper has more positive than negative units in

its atomic construction. In its positivities and negativities the copper atom is more evenly balanced than the zinc atom (§ 31). Therefore copper has slight affinity for the negative solution and has less attraction for the negative ether of the current than zinc. The copper plate plays a passive part, the zinc plate attracts the negative ether, and the positive ether takes the other route towards a point of neutralization and radiation. If oxygen were a solid it would be the best material for a negative plate; in fact, when highly oxidized substances are used as neutralizers of cations they constitute negative plates. A specifically negative plate would be active in its attractions.

Intensity of Action. The electro-motive force expressed in volts depends not only upon the *intensity of chemic affinity* existing between the solution and electro-positive plate, but also upon the *difference of potential* of the two plates in their relationship to the negative solution. It also depends upon the resistance within the cell. This resistance is decreased by enlarging the surface of the plates. When there is great intensity of chemic action the plates have to be removed from the solution, when the battery is not in use. When the chemic affinity is less intense, resistance to the radiation of heat prevents chemic action taking place when the circuit is open.

110. *Leclanche Cell.* The Leclanche battery has great constancy, fitting it for office purposes, and is selected for description in detail. The cell consists of a glass jar in which there is a rod of zinc—electro-positive—surrounded by a concentrated solution of chloride of ammonium. A porous cell within the glass jar separates the solution from powdered carbon mixed with peroxide of manganese. In the center of the

powdered carbon is a carbon plate—the electro-negative. The action within the cell is formulated as follows:

$Zn + (N\ H_4Cl)_2 + Mn\ O_4 = Zn\ Cl_2 + (N\ H_3)_2 + H_2O + Mn\ O_3$. By the formation of zinc chloride energy is given off. The ammonia evaporates through the various pores of the vessel. Hydrogen seeks the electro-negative plate, but meets and unites with oxygen, which is loosely held in the peroxide, water being formed. Hydrogen is thus intercepted and kept from polarizing on the negative plate. It is apparent that the real negative plate in the Leclanche cell is the peroxide of manganese.

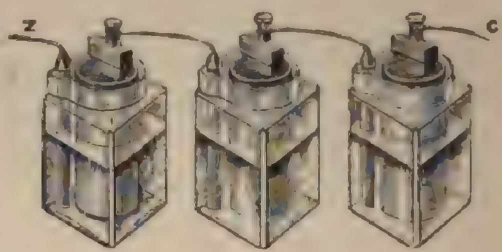


Fig. 43.
Leclanche cells joined in series: c, carbon plate; z, zinc plate.

111. *Daniell Cell.* The Daniell cell is a two-fluid battery. It has the following parts (Fig. 44): z, masses of zinc connected and forming the electro-positive plate; z s, semi-saturated solution of zinc sulphate; c s, saturated solution of copper sulphate; P, a porous earthenware vessel which keeps the solutions separate; c, sheet of metallic copper to which is fastened a copper wire, w, which is insulated by gutta-percha, and through which passes the positive current; crystals of sulphate of copper, c c s, are kept in the copper solution in order to keep the solution saturated; B, wire through which passes the negative current.

Copper, having a less positive potential (§ 36) than zinc, neutralizes in a less degree the radical SO_4. Therefore the molecule of copper sulphate has more potential than the molecule of zinc sulphate. According to the law that molecules tend to reconstruct under a lower potential the negative radical, SO_4, leaves the copper and unites with the zinc. The difference between the potentials of zinc sulphate and copper

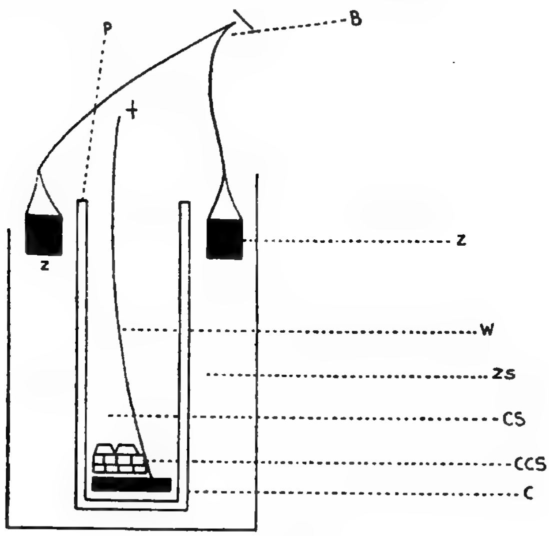


Fig. 44.
Diagram of Daniell Cell.

sulphate is set free as an electric current, that is, the zinc sulphate molecule has a smaller induced field than the copper sulphate molecule, and polarized ether is set free by the reconstruction.

The zinc plate is continually losing zinc and the copper plate is continually gaining copper molecules. The solution of copper sulphate is kept saturated from the crystals of copper sulphate. The chemic action is probably accomplished by displacement, there

being a general movement of the negatives, SO_4, towards the zinc, whilst the copper in combination is deposited on the copper plate. The reactions are illustrated by the following formulæ:

$$-\ Zn\ \begin{matrix}Zn\\SO_4\end{matrix}\ \begin{matrix}Zn\\SO_4\end{matrix}\ \begin{matrix}Zn\\SO_4\end{matrix}\ \begin{matrix}Zn\\SO_4\end{matrix}\ \begin{matrix}Zn\\SO_4\end{matrix}\ \begin{matrix}Cu\\SO_4\end{matrix}\ \begin{matrix}Cu\\SO_4\end{matrix}\ \begin{matrix}Cu\\SO_4\end{matrix}\ Cu\ +$$

112. *Dry Batteries. Chloride of silver battery.* The action of these batteries is on the same principle as the Daniell cell, a displacement movement of chlorine taking place towards the zinc plate as follows:

$$-\ Zn\ \begin{matrix}Zn\\Cl\end{matrix}\ \begin{matrix}Zn\\Cl\end{matrix}\ \begin{matrix}Zn\\Cl\end{matrix}\ \begin{matrix}Ag\\Cl\end{matrix}\ \begin{matrix}Ag\\Cl\end{matrix}\ \begin{matrix}Ag\\Cl\end{matrix}\ Ag\ +$$

The plates are surrounded by a paste in which the zinc chloride, or in some cells zinc sulphate, is imbedded. The electro-negative pole consists of silver chloride which is gradually reduced to metallic silver, the chlorine combining with the zinc, thus lessening the chemic potential. The dry cell is useful for movable batteries. The author has not found them sufficient for office work.

Storage Batteries or Accumulators. When electrolytic action takes place in a fluid and oxygen accumulates at the positive pole, it will act on the positive

plate if the plate be oxidizable. If the plate be non-oxidizable, oxygen forms on it and represents a chemic potential. It is clear that energy may be stored in this manner which will create sufficient difference of potential between the plates to cause chemic action independently of the potential of the fluid.

If two lead plates be immersed in water, acidulated with twenty per cent of sulphuric acid, and a galvanic current passed through the fluid, the oxygen will form an oxide of lead on the surface of the positive plate. If the current is reversed the oxygen will be driven to the surface of the other plate, which is thus oxidized. When this process is repeated a number of times, an oxide of lead is deposited on one plate, and on the other a coating of spongy lead. Thus a negative potential resides in the oxide of lead, and a positive potential in the spongy lead, and when the battery is removed a current manifests itself in the circuit in the opposite direction to the one last used in charging.

In order to have a more lasting current the lead plates are cast in moulds with holes or grids on their surfaces, and these are filled with oxide of lead mixed with sulphuric acid. The plates are then "formed" by passing a current through them and are ready for use. When the plates are connected in a circuit, part of the oxygen of $Pb\,O_2$ separates and unites with the spongy lead and forms $Pb\,O$; this action goes on until both plates are equally oxidized. The ether—energy—is set free when the oxygen unites with the spongy lead, the positive ether seeks the electro-negative plate, $Pb\,O_2$, and the electrode connected with it becomes the positive pole or anode.

113. *Arrangement of Cells.* Cells can be arranged in three ways:

1. The positive pole can be united to the negative of the adjoining cell and so on throughout the battery. This is called "arrangement in series" (Figs. 45, 46).

Fig. 45.
Cells Joined in "Series."

Fig. 46.
Representation of Cells in Series.

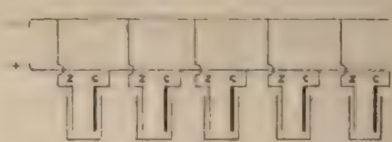


Fig. 47.
Representation of Cells in Multiple Arc.

2. All the positives may be joined together, likewise all the negatives, which is called arranging "in multiple arc" or "abreast" (Fig. 47).

3. They may be arranged partly under one system and partly under the other.

Edison Incandescent Current Mains. Suitable apparatus for the control of the current from the Edison incandescent current mains are furnished by manu-

facturers. For safety, the circuit should be entirely under the physician's control, as in private plants; or the supply mains must be beyond the risk of receiving powerful arc-light and trolley currents from broken wires. The voltage controller should be graded so as to be able to select 20, 50, 75, or 110 volts. The current should be modified by an effective graphite controller. The operator should be able to apply currents from one-fourth milliampere up to 250 milliamperes. The determination of the polarity of the wires may be made by placing them on blotting paper wet with a solution of potassium iodide, the iodine appearing at the positive pole.

Rheostats or Current Controllers

114. Instruments intercalated in the circuit for the purpose of modifying the current, are numerous.

Hydro-rheostat. The water rheostat consists of a body of water interposed in the circuit. The cross sectional area, or the length of the body of water, may be increased or decreased thus influencing the current.

Monell Rheostat. This instrument registers the dosage of secondary coil currents. The resistance that a certain current is capable of overcoming is ascertained and the strength of the current thus recorded. Monell describes the instrument as follows: "This rheostat consists of two glass tubes marked 1 and 2. They contain compound fluids, one of high and the other of low resistance. The resistance of the first tube is practically 1,000,000 ohms, and is sufficient to control the full coil, high tension current, and reduce the perception of it to zero in the most delicate application to a patient.

"The second tube possesses a much lower resistance (55,000 ohms) for currents of less potential and for gynecological uses. The fluid in either tube, selected at will by a switch, regulates the dosage by means of an adjustable rod regulated at different heights of the column."

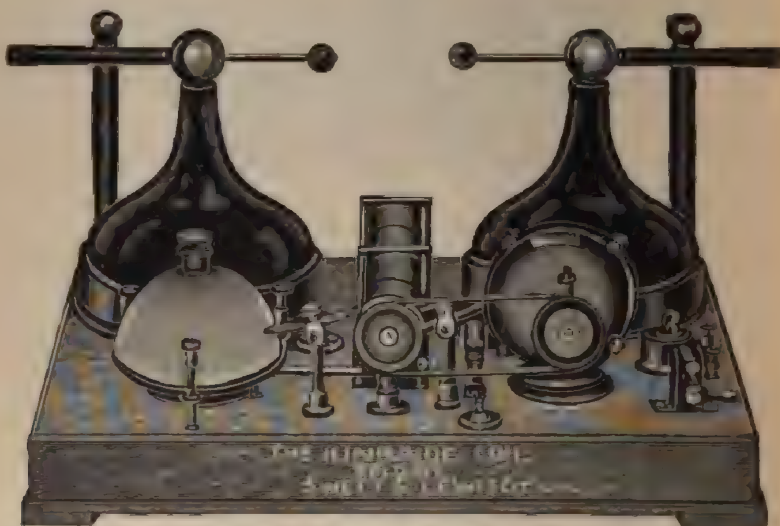


Fig. 48.
Kinraide Roentgen Ray Coil.

The Massey Current Controller. The Massey current controller consists of a slate disc roughened to retain a graphite coating. When the arm or brush is at the point marked "start" (Fig. 49) the circuit is open. When it is connected with the graphite point the circuit is made, but the resistance is great. As the handle is turned the resistance is lessened by an increase of the cross-sectional area of graphite coating and the current is increased accordingly.

Fig. 49.
Controllers.
The McIntosh and the Massey.

Electrodes

115. The material from which electrodes are manufactured is of great variety. *Sponge*, because of its capacity for holding water, is very useful, especially for small electrodes. *Absorbent cotton* has advantages in that it may be thrown aside after using. In vaginal applications it is indispensable. Cotton is not useful

for labile applications, because it packs under pressure and does not hold water so well as felt. *Felt*, the thick, firm, white variety used on piano keys, is very satisfactory for medium sized electrodes and when moderate dosage is indicated. For very large dosage of the galvanic current *clay* makes the best electrode. The kind called potters clay is superior. Clay adjusts itself to the skin, holds water well, and allows the current to enter the skin in such an evenly distributed manner that a larger current can enter without irritation or pain than with any other substance employed. It is not used unless very large amperage is required. Moulds of different sizes can be had from the instrument makers which can be filled with the material when desired.

116. *Care of Electrodes.* All electrodes become corroded by the positive current with the exception of those made of platinum or gold. Nickel is but slightly corroded. Sponges should be washed and disinfected. Fastidious patients may supply their own sponges. Covers may be used for the electrodes and washed like towels. Absorbent cotton can be used as a covering. Clay, felt, sponge, and cotton, used in their separate places as dosage and location indicate, give more satisfaction than other available material. It must be kept clearly in mind that the material of these electrodes is not the conducting agent, but the water in their meshes, and that water itself is greatly improved as a conductor by being alkaline. This is best effected by adding a teaspoonful of bicarbonate of soda to a pint of warm water. Common salt is not as good as the bicarbonate, as the chlorine when set free corrodes the electrode.

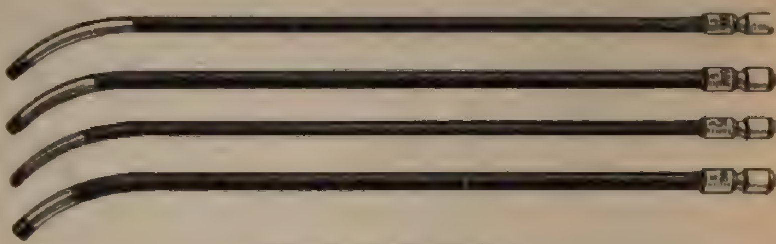
117. *Water Electrode.* Water or an alkaline solution can be used as a bath-electrode. Any vessel of the

necessary dimensions may be partly filled with water, and the terminal of the conductor, and the part of the body to which electricity is to be applied, placed in the liquid. This is an excellent method of equalizing the current over the smaller joints, or over such parts of the body as can be immersed in the liquid.

118. *Metal Electrodes.* Without covering these are needed for special applications. With the galvanic current they are seldom used on the cutaneous surfaces, but on mucous surfaces within the cavities of the body they are indispensable. Needles for the purpose of puncturing tissues are also necessary.

Metal electrodes differ in the material of which they are composed, and in the shape and size necessary for adaptation to the cavity. As metals are electro-positive the ions at the negative pole do not chemically attack them. Any metallic substance therefore may be used for a negative electrode. But with the exception of platinum and gold all metals are decomposed by the electro-negative ions that are attracted to the positive pole, by the inductive influence of the galvanic current. By the employment of an electrode other than platinum or gold, the substance of the electrode suffers and the tissue may be undesirably affected by the decomposed metal. Gold being expensive, platinum is used for positive electrodes when punctures or intra-uterine applications are being made. Carbon and pure tin can be used for positive electrodes when the current is below medium dosage.

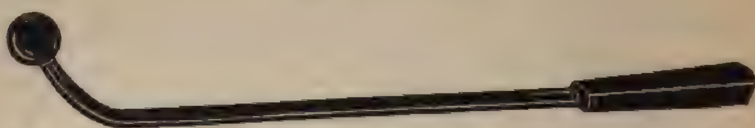
When it is desirable that the special effect of a nascent salt be added to the effect of the current, then such material as copper, zinc, etc., may be employed as positive electrodes (§ 63).



Intrauterine Electrodes.

Bipolar Vaginal Electrode.

Vaginal Electrode.



Carbon Ball, Vaginal Electrode

Goelet's Clay Vaginal Electrode.

Fig. 50.
Electrodes.

The size of the electrode depends upon whether diffusion or concentration of the current at the particular pole is desired. The shape most available depends altogether on the surface to which it is to be applied.

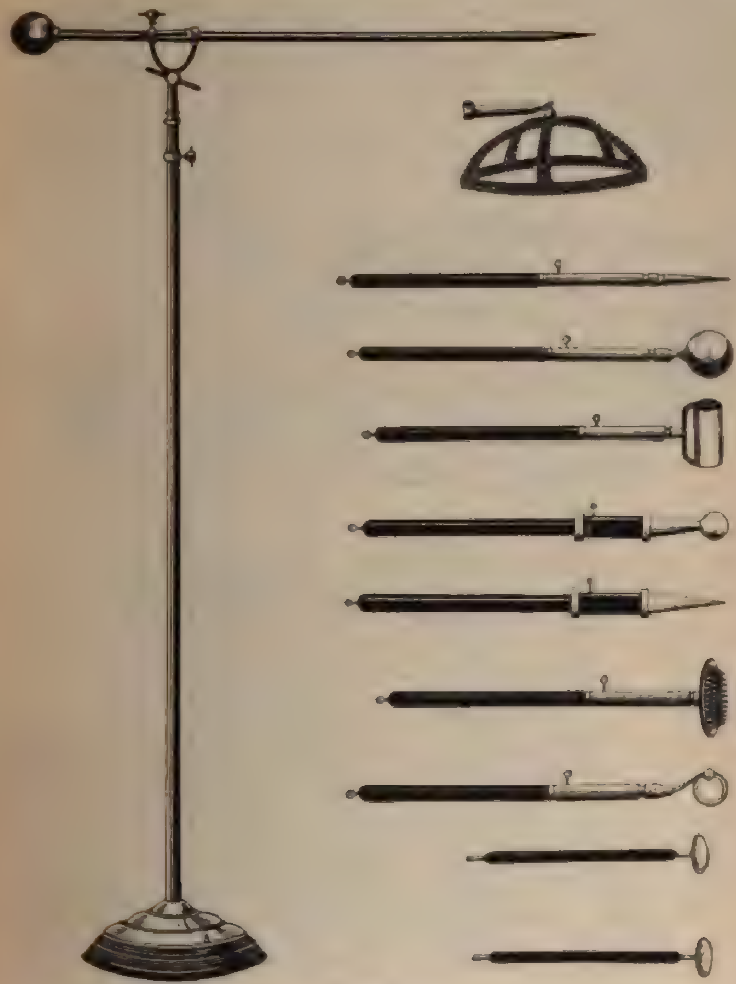


Fig. 51.
Combination Ball-point Electrode and Crown, and Set of Electrodes for Static Machine.

119. *Faradic Electrodes.* Faradic electrodes are usually small and compact, large dispersing surfaces being unnecessary. As no electrolysis results the positive chemic action on electrodes is absent. Sponge, absorbent cotton and felt may be used as with the

galvanic current. The faradic brush is suitable for stimulating paralyzed surfaces. Bipolar electrodes are only used with the faradic current. Vaginal and intrauterine bipolar electrodes are very useful in gynecological electro-therapy.

Fig. 52.

A, Apostoli's Abdominal Clay Electrode with Contact Plate and Zinc Tray for keeping clay moist; B, Sponge or Felt Electrodes.

120. *Active and Indifferent Electrodes.* These are terms in general use. An active electrode is one applied directly to the locus morbi, and is positive or negative as the case indicates. The indifferent electrode is placed on any suitable part of the body in order to

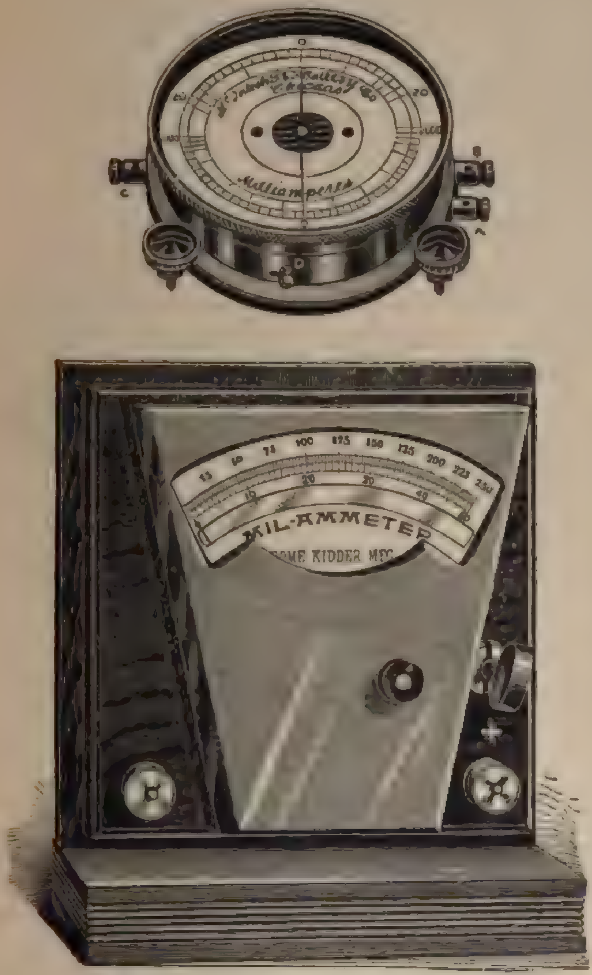


Fig. 53.
Milliamperemeters.

complete the circuit; it may be of any size, but generally is as large as consistent with its adaptation to the parts. It is sometimes spoken of as the dispersing electrode. The active electrode is usually small in order to concentrate the current at the point of application.

MILLIAMPEREMETERS

121. The principles of current-measurement have been explained in another chapter (§ 105). No application of the galvanic current should be made without knowing the dosage employed. The meter more than any other instrument justifies the claim of electro-therapy to scientific exactness, and electro-therapeutists should see that they possess an accurate instrument according to standard measurements. Some of the instruments on the market possess standards of their own. The Committee on Meters of the American Electro-Therapeutic Association made the following report:

PUBLISHED TEST OF THE COMMITTEE ON METERS IN 1896

NAME OF METER	MILLIAMPERES READ IN TEST											
Weston, 0 to 500....	12	15	20	30	40	50	75	100	125	150	200	250
Kennelly, 0 to 100.	12	15	20	30	39	49	74	98				
Kennelly, 0 to 150.	12	15	20	30	40	50	74	99	123	148		
Chloride, 0 to 250 ..	12	15	21	31	43	55	80	100	135	165	225	
Jewell, 0 to 300......	11	14	19	28	37	47	70	94				
McIntosh, 0 to 300..	11	14	19	29	38	49	74	97	125	148	200	275
Kidder, 0 to 250.....	12	15	21	30	40	50	75	98	125	148	205	252
Vetter, 0 to 250	12	16	21	32	40	52	78	108	129	152	212	251

In the test the Jewell meter was withdrawn on account of an accidental injury it had sustained in transportation. A good meter should be free from the perturbing influence of proximating bodies of iron and steel. The same committee subjected the following meters to the severe test of a new 8-inch permanent magnet brought close to them, with the following results:

Vetter,	no deflection.
Jewell,	4 milliamperes.
Weston,	5 "
Kennelly,	5 "
Kidder,	75 "
McIntosh,	off scale entirely.
Chloride,	" " "

By a good meter the electro-therapeutist is able to measure minute currents even to the tenth of a milliampere, as needed in ophthalmic practice, up to 250 or 500 milliamperes, as required in gynecological work. The instrument therefore should have different scales, which is accomplished by shunting part of the current, making accuracy of calculation practicable.

122. *Pole Changer or Current Reverser.* For the purpose of rapid reversal of the direction of the current—voltaic alternation—galvanic batteries usually have a simple switch attached. More complicated instruments have been devised by instrument makers, but the simpler form sufficiently answers the purpose of the operator.

Fig. 54.

Galvanic Switchboard. With circle of 36 buttons, double selecting switch, pole changes and binding posts.

CHAPTER VIII

Radiant Energy

123. *Ether Changes.* In the galvanic cell, by lowering chemic potential, polarized ether is transformed into atomic ether—the electric current. In the electrolyte the atomic ether again becomes molecular, polarized in the induced field of a chemic potential. In thermo-electricity a molecular ether-stream as heat is transformed into an electric current which again is converted into heat. In the incandescent lamp atomic ether becomes molecular and manifests itself as light, and in the spark of a static machine the light phenomenon is coincident with the formation of molecular ether. In the various transmutations of force there is involved a degree of waste chiefly represented as molecular ether radiating as heat.

124. *Transmission of Energy.* By radiant energy is meant energy transmitted from a source and producing effects at a distance. The transmission may take place in one of two ways:

1. By actual transfer of matter carrying the energy with it, as in the case of a bullet or charge of shot from a gun. Energy transmitted in this way is characterized by moving from the source to the distant point in straight lines, if not subjected to other forces on the way. The energized particles of matter constitute *real rays*, and an obstacle in their path

will cast a shadow sharply defined, that is, the shadow of the obstacle will correspond exactly with the geometrical shadow. The conveyance of electric energy through air or other dielectric medium, the cathode rays in a Crookes tube, and the Roentgen rays are instances of this method of transmission. The passage of the galvanic current through fluids may be similar to a real ray.

2. The transmission may take place *through a medium with slight if any displacement of matter, each particle of the medium conveying the energy to the surrounding particles by a vibration on its axis, but maintaining its relative position.* Transmission of this character constitutes *wave motion.* The rays are not real as in the first class, their shadows are not sharply defined, and they are transmitted to some extent within the geometrical boundary of the shadow.

125. Wave motion is distinguished by interference and refraction phenomena from genuine rays. The vibration of each particle of the medium may take place longitudinally or in the line of propagation, or it may take place transversely or at right angles with that line. Energy traveling as a real ray may be transformed into the energy of wave motion, thus a cannon ball striking a target has part of its energy converted into a flash of light.

126. *Sources of Wave Motion :*

1. The kinetic energy of the electric current—ether atoms combining and forming molecular ether.

2. Chemic action—molecules of ponderable matter being reconstructed under a lower potential and setting free polarized ether from their induced fields.

3. Compression of matter—intermolecular ether forced from the compressed body.

4. The ether in the path of a body of great kinetic energy and of great inductive potential is polarized as the body passes through it.

Associated with all light and heat phenomena is the setting free of ether in the molecular form. The two principal factors in the production of heat and light radiation are as follow:

1. The extensibility or impenetrability of the ether molecule which has been set free.

2. An equilibrium existing between all forms of matter, including ether, in relation to space, which certain forces tend to preserve (§ 38) and which the freed ether disturbs.

But for other forces the ether molecules set free, as from an electric current, would form a so-called vacuum—a space containing no matter excepting ether—or, if set free by chemical action, the ether molecules are placed intermolecularly in excess of the molecular potential of the newly formed ponderable substance; both of these conditions are disturbances of the equilibrium of matter. Molecules and masses of ponderable matter, pressing together by gravitation, force the ether to move in the opposite direction, and set up the wave disturbances known as heat and light.

127. *Wave Motion.* Wave motion is modified by:

1. The intensity of the potential that created the energy.

2. The rarity or density of the medium through which the energy is propagated.

Wave radiations vary in frequency from 10 million millions to 1,622 million millions per second of time. The frequencies that affect the eye physiologically are

comprised within 392 million millions and 757 million millions, the portion of radiant energy between these limits is known as light. Except in the matter of frequency, light does not differ in any respect from wave radiations in general. Between the limits of vibratory frequencies that affect the eye there are many distinct frequencies recognized as light. Color is defined objectively by the vibration-frequency required to produce it.

CONSTANTS OF LIGHT WAVES

Color	*Vibration-frequencies per second*	*Wave-length in air centimeters*
Ultra-red	370 million millions	00008100
Red	428 " "	00007000
Orange-red	483 " "	00006208
Orange	502 " "	.00005972
Orange-yellow	510 " "	00005879
Yellow	516 " "	00005808
Green	569 " "	00005271
Blue-green	590 " "	00005082
Cyan-blue	604 " "	00004960
Blue	634 " "	00004832
Violet-blue	684 " "	00004383
Violet	739 " "	00004059
Ultra-Violet	833 " "	00003600

128. *Fluorescence.* By passing an ultra-violet ray through a solution of quinine or aesculin a blue light will be observed. The high frequencies of the radiations are reduced by the vibrations of the quinine so that they strike the eye physiologically. Decreasing vibratory frequencies is known as fluorescence. Other substances, such as fluor-spar, fluorescein, eosin, thal-

lium, uranium and some hydro-carbons, also possess this property. The production of luminous from non-luminous radiation of less frequency has been called *calorescence*. This property is possessed by certain substances such as lime and platinum under proper conditions.

129. *Frequencies of Radiations.* If a current is passed through a circuit in which there is placed a piece of platinum wire giving the maximum resistance of the circuit, neutralization of the atomic ether will take place in the platinum. The nascent molecular ether around the platinum tends to form a vacuum which the atmospheric pressure renders impossible. The mixing of the newly formed molecular ether with the air is a disturbance in the equilibrium of matter, and in its results it is similar to throwing a stone into water. Waves thus radiate from the disturbed center the intensity of which is measured by the degree of temperature, or number of ether molecules disturbing the equilibrium. As the force of the current is increased the number of nascent molecules of ether is increased, and as each molecule has to occupy a place, the number of waves corresponds to the number of nascent molecules. The frequency and amplitude of waves must be directly proportional to the number of newly formed ether molecules; or if the ether comes from molecular polarized fields readjusted, the frequency and amplitude will be directly proportional to the number of ether molecules depolarized or set free, in a given time. As the ether molecules set free pass through the induced fields of ponderable molecules by displacement, and as the radiation meets differential resistance, the waves are modified by the character of the medium (Figs. 70, 71) and by the vibratory balance of its molecules (§ 1).

At the commencement of the current the vibrations are merely appreciated as a sensation of heat. As the amperage is increased, the amount of nascent ether is increased ,and consequently the number of vibrations. When there are about 392 trillions of molecular births per second, each birth is announced by an illumination which appears as dull red. Each increase in number of nascent molecules of ether gives a corresponding increase of vibrations and a consequent change of color. When the vibrations number 757 million millions per second, the lower light vibrations being also present, the platinum is at a white heat.

Lights differ physiologically or subjectively in their intensity and color. In an objective or physical sense light differs as to reflection, refraction or velocity through bodies of different densities, as well as in diffraction and interference phenomena.

Roentgen Rays

(*X Rays*)

130. The essential character of electric energy for the production of the Roentgen rays is an interrupted current of great tension. This may be furnished from an induction coil or from an electric apparatus such as the Holtz or Wimshurst machine.

The important factor in the generation of the Roentgen rays is the condition of electric discharge, or electric neutralization. It is absolutely necessary that this should take place in a rarefied medium. The rarefaction is effected by exhausting a glass globe or tube to a very great decrement. This tube receives its name from the degree of exhaustion. A Geissler tube is exhausted to about the one thousandth part, and a

Crookes tube to about the one millionth part of ordinary atmospheric pressure. The tubes may be of any shape convenient for special purposes. The degree of exhaustion of the tube, the form and disposition of the poles, and other details of construction may be varied according to the experiments intended.

131. The *Geissler* tubes contain a residuum of air, oxygen, nitrogen, hydrogen, carbon dioxide, etc., each gas exhibiting a peculiar light when traversed by an interrupted current of high potential. At the negative electrode of the tube there appears a beautifully luminous phenomenon. These tubes produce Roentgen rays feebly, if at all. This is probably owing to the exhaustion not being sufficient to dissociate, or to allow the current to dissociate, the molecules of the residuum.

132. The *Crookes* vacuum tubes exhibit certain distinctive phenomena. The radiant energy emanating from the cathode is called the cathode rays. It is a stream of luminous matter sent out on straight lines perpendicularly to the cathodal surface, and independently of the position of the anode, which may enter at any part of the tube without affecting the direction of the radiant stream. The cathode rays strike against the opposing object which has been called the bombarded surface. It is better that the cathode be concave, thus focusing the rays and giving a small bombarded area. The Crookes tube at the bombarded spot manifests a singular illumination which has been characterized as fluorescence.

The *cathode rays* have distinctive characteristics. Professor Crookes showed that they possessed mechanical properties and were deflected by a magnet. Jean Perrin proved that they were negatively charged, and

capable of charging a body. The cathode rays produce fluorescence, affect a photographic plate, and have a certain degree of penetration through opaque bodies, depending on the potential of the current, the rarity of the residium and the character of the medium. The experiments of Leonard, Crookes, De Kowalski and others with the cathode rays, were preparatory work, which made the discovery of Prof. Roentgen possible.

The cathode rays heat the object bombarded; a thin lamella of glass placed in their path will be molten. Crookes showed that they were capable of driving a small mill placed so as to receive them on its wings. When taken from the tube in which they originate to another tube they will discharge an electroscope. Their properties do not depend upon the nature of the residual gas, a fact which makes it probable that the atoms of all gases are dissociated and for the time lose their identity.

133. The *Roentgen rays* have their origin at the bombarded spot in the Crookes tube. The radiant energy is transformed at this point, and one of the results of the transformation is the development of the Roentgen ray.

When an energized Crookes tube is placed within a black card-board muff which intercepts its light, and then placed in a dark room so that it approaches a screen painted with some phosphorescent substance, the substance begins to glow, although no light is visibly falling on the screen. If a metallic substance is placed between the tube and the screen, its shadow will be seen on the screen, but a book and various other substances opaque to ordinary light will cast no shadow. Placing the hand in the same position, there is projected on the screen dark shadows of the bones, but

almost no shadow of the flesh. These and similar phenomena are produced by the Roentgen rays.

134. The characteristics of the Roentgen rays are as follows: They affect the photographic plate and produce fluorescence in certain salts. They pass through substances entirely opaque to ordinary light, as paper, wood, hard rubber, flesh, etc. They have

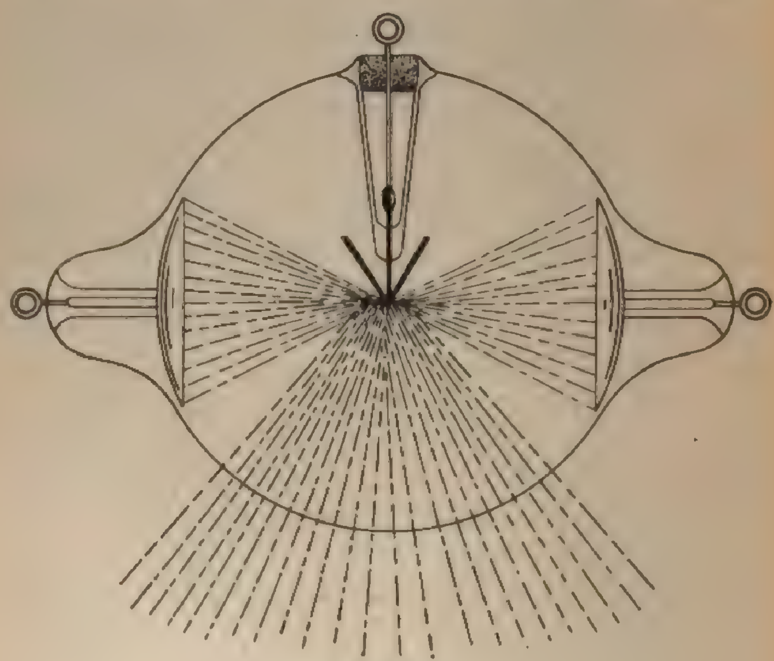


Fig. 55.
Standard X-Ray Tube.

distinctive relative power in penetrating flesh and bones. They are not electrically charged, but discharge bodies already charged. When falling on the air surrounding a charged body they render the air a conductor of electricity, and thus effect the discharge of the electrified body.

When the Roentgen rays strike against metallic surfaces they are not deflected but irregularly diffused. The diffusion differs from reflection, not only in its irregularity, but also in the important fact that the rays

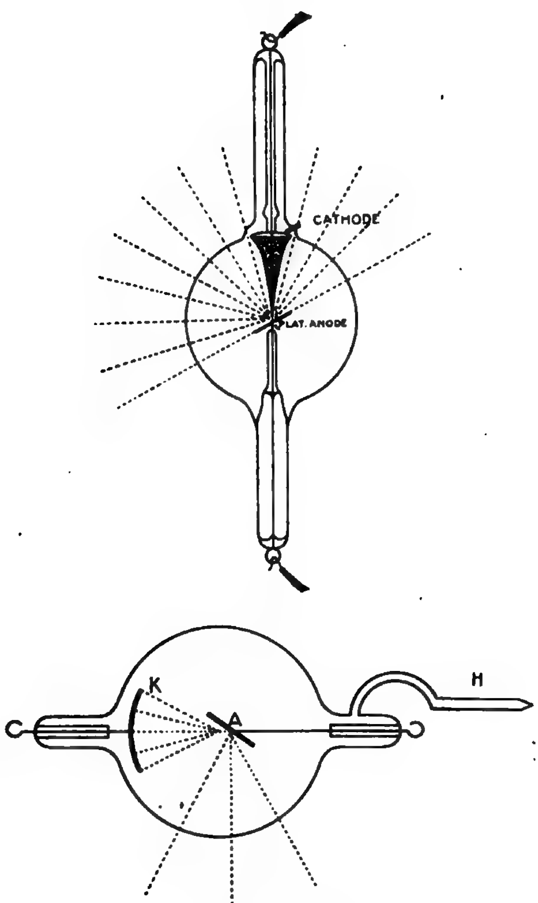


Fig. 56.
Typical Tubes.

themselves are changed in character. In this change they approach more to ordinary light, and their power of penetrating through flesh and wood is diminished.

In the latter fact there is a remarkable analogy between the Roentgen rays and ultra-violet radiations.

When the Roentgen rays are of great intensity they become visible, affecting the eye physiologically in the peripheral parts of the retina, which contain more rods than the central parts. As the pressure in the Crookes tube is lessened to a definite minimum and the potential of the current proportionately increased the Roentgen rays become more penetrating. If the tube is made a perfect vacuum, containing nothing but ether, there is no conducting medium and therefore no electric current (§ 38). With a maximum decrement consistent with electric conduction and under the greatest pressure, the rays will pass through metals, shells, etc.

The comparative resistances offered to the passage of Roentgen rays through the organs of the human body is distinctively characteristic. The bones, liver, and denser tissues present dark shadows, whilst the lungs and less dense tissues barely cast a shadow. Bullets of lead and other metallic opaque substances cast dark shadows and are therefore easily detected. Displaced bones, as in fractures and luxations, are unerringly photographed.

135. *Theoretical Considerations.* The position of the Roentgen rays among the phenomena of light has not been definitely settled. In an article on the subject published in *Archives of the Roentgen Ray*, London, May, 1898, and also in the *Electrical Review*, New York, March, 1898, the author advanced the theory that the rays consisted of *dissociated* ponderable atoms. In view of the hypothesis that ether atoms can be dissociated and therefore exist apart as positive and negative electricity, it is probable that with an extreme potential ponderable atoms, as subnormal molecules,

for a time at least, may be made to do likewise. It must be kept in mind that the great decrease of pressure in the tube is favorable, not only to disruption of molecules, but also to tearing asunder the so-called

Fig. 57.
X-Ray Tubes.

chemical elementary atoms. Consequently any of the countless degrees of condensations of matter (§ 19) between the real elementary unit—the ether atom—(§ 20) and the so-called chemically elementary atoms

Fig. 58.
Queen Self-regulating X-Ray Tube.

may be artificially produced by the great decrement of pressure, even without electric action.

136. The conditions are these: At the cathode there are negative ether atoms under a high pressure, and at the anode positive ether atoms also having great potential. The attractions and repulsions of the ether atoms are pressing them forward in the way of neutralization. Although the anode may enter at any part of the tube, it is absolutely necessary that entrance be made.

Neutralization of the electric current *must* completely

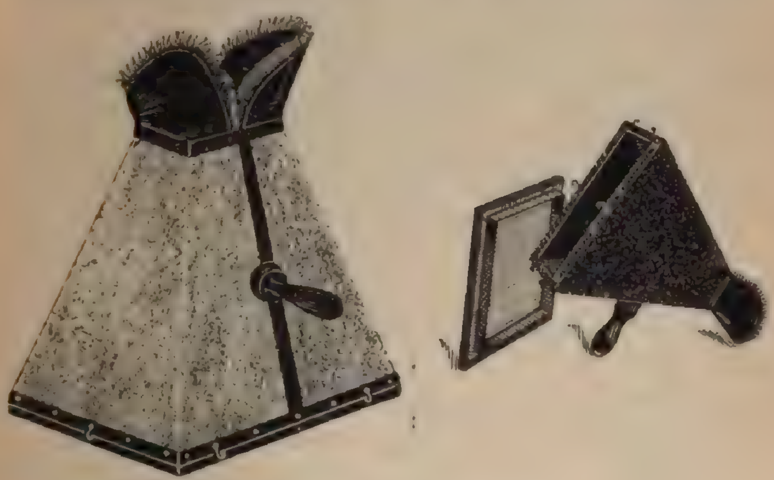


Fig. 59.
Fluoroscope and Screen Detached.

take place in the tube owing to the great resistance met in that part of the circuit. The molecules of the residual gas, reduced in size and simplified in construction but raised in potential by the extreme decrement, approximating the electrodes, are electrified positively and negatively, respectively. These molecules do not undergo electrolysis at the cathode, as the first step in electrolytic dissociation takes place at the point of neu-

tralization (§ 53). The character of the gas particles does not affect the electrification, as any substance can be electrified either positively or negatively, when not in the presence of other substances having greater attractions for the electrification. The residual gas, however, will have its more electro-positive molecules (disintegrant molecules) attracted to the cathode, and its more electro-negative to the anode.

The important factors in directing the course of the electrified particles are the repulsion of the negative current—inherent diffusibility of negativities—and the comparative size of the particles electrified by negative ether; and these particles differ from those positively electrified (§ 61) as the molecules of hydrogen differ from those of oxygen. The kinetic force is sufficient to overcome the attraction of the anodal electrification, and the cathode rays go forward in a straight line independently of positive attraction. The positive current, however, without reference to the location of the anode, undoubtedly meets the cathodal stream at the bombarded point. Consequently here is where neutralization takes place, and this fact accounts for the illumination, which is similar to a spark. The fact of the cathode rays taking a course independently of anode attraction points to an inherent repulsive force in negative ether atoms. This important fact admits of no other explanation than that the kinetic potential of cathode particles is based on the fundamental principle of repulsion or diffusibility possessed by negative ether-units; and the action of this principle is shown by mutual repulsion on the part of the units of negative electricity as manifested in the cathode stream. There is no analogous fact pointing to a similar principle of action on the part of positive electricity, but

facts point to a concentrativeness on the part of positivities.

A lamella of glass placed in the path of the cathode rays will obstruct them so that neutralization of the electric current takes place in the glass, hence the molten state. By this arrangement, between the

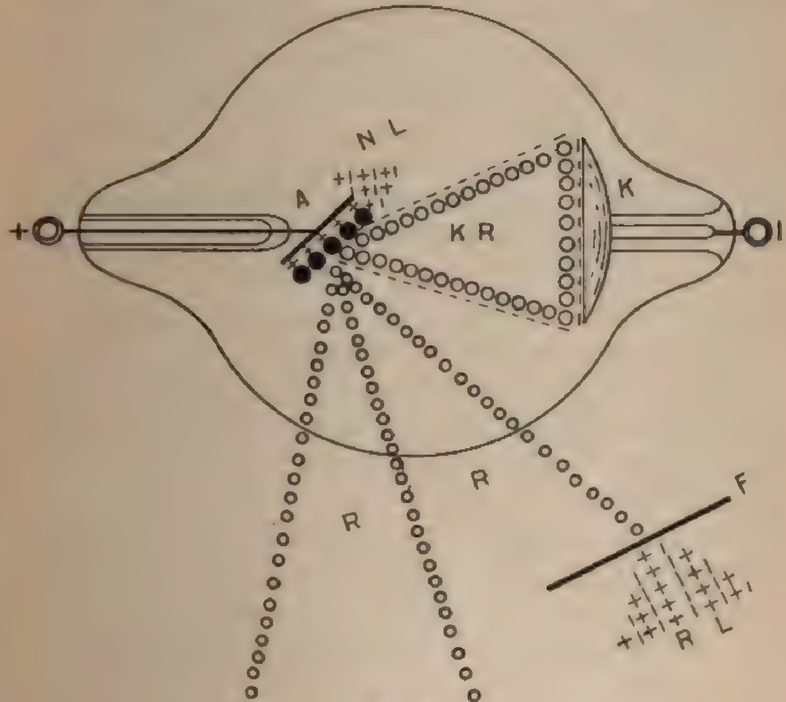


Fig. 60.

Crookes Tube with Vacuum Rays. ●, negative submolecules attracted to anode; O, positive submolecules attracted to cathode and shown as charged in cathode rays; A, anode; K, cathode; K R, cathode rays composed of charged positive submolecules; N L, light at bombarded spot from neutralization of positive and negative ether of electric currents; R R, Roentgen rays composed of positive submolecules reduced in size from the cathode molecules; F, fluoroscopic substance obstructing Roentgen rays and emitting light waves; R L, molecular ether from the induced fields of the submolecules neutralized by the fluorescent substance, the ether radiating as light.

lamella of glass and the apparent anode there will be *anode rays*—a stream of negative matter positively charged. It would be interesting to know the differential character of anode rays, the propelling power in which is attraction between positives and negatives. On the other hand the predominating propelling power of the cathode rays is the inherent repulsion of negatives, attraction between positives and negatives being a subordinate force.

137. In discussing electrolysis it is pointed out that the newly formed molecular ether follows the course of least resistance, and in electrolysis the molecule of ether acts on a molecule of ponderable matter (§ 53). At the bombarded spot the newly formed molecular ether must follow one of two courses: (1) It may find room for itself amongst the ether molecules in the tube, thus setting up wave radiation; or (2) it may disrupt a molecule of the gas into component parts of higher potential, as in the first step of electrolysis. The illumination of the bombarded surface proves that the nascent molecular ether partly follows the first course. The evidence, however, favors the conclusion that part of the newly formed ether molecules follows the second course. In this they are assisted by the tenuous condition of the gas in the vacuum.

138. The negatively electrified particles of the cathode radiation which belong to the electro-positive elements of the residual gas, striking against the opposed surface—the anode—lose their electrification by neutralization. The following forces act within the tube and are to be considered as factors in the production of Roentgen rays:

1. The bombardment impelled by the tremendous kinetic potential of the cathode stream.

2. The ether molecule, formed by the neutralization of the positive and negative currents, concentrating on the cathode particle.

3. The attraction of the cathode for the cathode particle after the latter has lost its electrification at the bombarded spot.

4. The extreme decrement of the tube favoring tenuity. This, however, acts on the residual gas independently of the current.

If the gas in the tube has reached an extreme decrement—the positive elements of the gas being equal to the primary condensations—no further disruption of the cathode particles by electrolysis is possible, and in this case the Roentgen rays ought to be identical with the cathode rays, only they are not electrically charged. Then the electric current is transformed into light or heat waves within the tube, or the nascent ether molecules may act upon the electro-negative molecules at the anode, which may be further dissociated, the component resultants seeking their respective poles. On the other hand if the cathode particles admit of further dissociation by the electrolytic action of the nascent ether molecules the latter will be polarized by the higher potential of the dissociated elements, and carried along in their induced fields. It is evident that in any case the Roentgen rays are composed of subnormal molecules of positive quality which have reached the limit of dissociation, and that they have a very high inductive potential and accordingly very large induced fields (Fig. 61). As they are reflected from the bombarded spot they retain the kinetic potential of the cathode stream, but the inductive attraction of the electric current must

modify their course by directing them towards the cathode.

139. A ray composed of such minute elements is possible from the fact that the particles have weight; whereas the projection of an ether stream is impossible as the ether molecule cannot have kinetic potential, not having weight. Because of the minuteness of its particles such a ray has greater penetrating power than that of any other known real ray. The Roentgen ray discharges positively and negatively charged bodies by rendering the air a conductor, thus interfering with the insulation of the charges. Dry air has molecular inter-

Fig. 61.

Radiant Molecule of Roentgen Ray, 1/1000 of the mass of the hydrogen atom but immensely greater in potential. The plus-symbol on the sphere denotes the constituent quality of its inductive potential; and the plus and minus-symbols denote the induced polarized field. The tridimensional space occupied by the molecule and its induced field may be larger than the similar space of the hydrogen molecule.

spaces on which are based its insulating properties, and the ray, through polarization, may bridge the interspaces, thus improving the conduction. The radiant particles, however, may be electrified by passing through a charged body, and become carriers of electricity as in the cathode rays, or as air molecules are in rupture of that medium.

The Roentgen ray is not deflected by a magnet having no electric charge on the surface of its particles. Inside the tube the dissociated particles are normal or approach normal, as to equilibrium; outside the tube they acquire a potential from the changed condition of environment relative to their sub-normal condensation.

In the cathode stream the molecules are electrically charged, and the intimacy between the charge and the constituent units of the molecules may be similar to the relation between the constituent units of molecules differing only in degree, and relative placement.

140. Although the Roentgen rays as they issue from the Crookes tube consist of minute particles having great potential because of their tenuous state, and having great kinetic force, it is possible that on meeting resistance in their path their character may be changed. On striking an impenetrable substance such as bone their potential is converted into heat, and they chemically unite with their own or with adjoining molecules. Their passage through semi-translucent substances, such as flesh, etc., is attended by an expenditure of kinetic potential, which allows reconstruction of their particles either between themselves or with the medium, consequently molecular ether is set free from their induced fields (§ 29), and from this onward the Roentgen rays are wave radiations. Thus the Roentgen rays are compound. Starting as real rays of particles, consisting of minute molecules of the primary condensations of matter, and ending as waves of ether, perhaps of the ultra-violet variety but reducible in frequency. The great dark unknown immensity of light designated ultra violet, in part may be analogous to Roentgen rays in being constituted of real rays followed by wave radiations.

It has been stated that with a high electric potential and great gas decrement the Roentgen rays are visible to the eye. Under these conditions the molecules are probably broken up to a degree identical with the positive primary condensation, and have a maximum kinetic potential. They are still carriers of electricity as long

Fig. 62.

Synovitis of shoulder joint from railroad injury, six weeks after occurrence. The radiograph shows the surrounding tissues thickened.

as there are unsatisfied units within their construction, a satisfaction only attained in the ether molecules. They are also capable of projection as long as gravitation has power over them (§ 39).

141. The visibility of the rays when under great potential may be accounted for as follows: The particles having large induced fields in proportion to their size, and having to carry the polarized ether in their induced fields, or create new fields—polarize the ether in their path—they may take the latter course as the one of the least resistance. This course is favored by the polarized ether in the induced fields offering resistance, and by the immense kinetic potential. The ether therefore along their path may be alternately polarized and depolarized, hence visible light waves. This explanation also applies to the cathode stream. However, if the residual gas, owing to extreme decrement and high potential, is reduced to an extreme diffusibility at the bombarded spot, wave motion must take place from that point, hence visibility.

142. The cathode rays are no doubt broken-up gas molecules, but there can be no force at the cathode itself to effect the disintegration (§ 53). Here they are merely electrified, as it requires two electric forces to tear a molecule apart. The dissociation is either effected by the tenuity of the gases in the tube, or by the neutralized positive and negative ether (§ 53). The neutralization does not take place in the cathode stream, otherwise its particles would not be electrically charged. Part of the stream issuing from the bombarded spot may return to the cathode, and thus the cathodal electrification follows as well as precedes the bombardment in the cycle taking place within the tube. The illumination of the cathodal rays is the

Fig. 63.
Colles' Fracture, Four Weeks After Occurrence.

alternate polarization and depolarization of the surrounding ether by an electric charge carried through it at a high velocity.

Experience has shown that the Crookes tube "wears out." This is probably due to the residual gas being

projected from the tube in Roentgen radiations. In this case the tube becomes a complete vacuum, and there being no carriers of electricity—the ether molecules being entirely self-neutralizing—the circuit is broken.

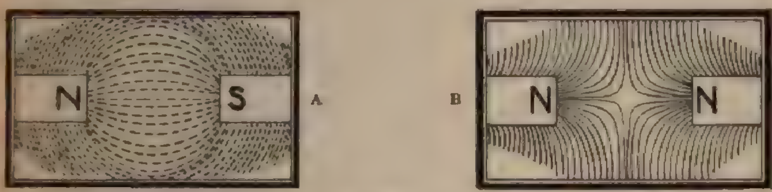


Fig. 64.
A, showing absorption of Induced Force; B, showing impenetrability and distortion of Induced Force (associated with Fig. 17).

Rays Analogous to the Roentgen Ray

143. Certain substances possess the property of emitting light in the dark. Uranium, sulphide of lime, barium, calcium, strontium, and other substances glow in the dark after being exposed to light.

M. Henry discovered that phosphorescent sulphide of zinc gave out radiations that passed through black paper and affected the photographic plate M. Becquerel studied these radiations under all possible aspects, and hence they have been known as the "Becquerel rays." Two chemically elementary substances have been discovered through experimenting with these rays by Madame Sklodowska-Curie, and her husband, M. Pierre Curie. These substances have been named polonium and radium.

Phosphorescent bodies emit light which is visible to the eye, and there are also invisible radiations, which bear strong resemblance to the Roentgen rays. Moreover, the Becquerel rays differ from fluorescence, in the

fact that after stimulation by light, the substances continue indefinitely to emit light. These rays are deflected by a magnet; they carry electricity and they render the air an electric conductor, thus resembling the cathode rays. They are like the Roentgen rays in that they cannot be reflected or polarized.

The radio-activity of substances is relative. Uranium and its salts hold the first place. Thorium strongly possesses the property. If, however, polonium and

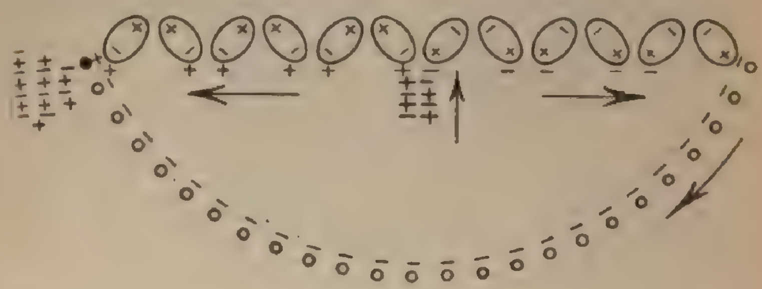


Fig. 65.

Molecules splitting up ether into light-radiations. The symbol ● represents an electro-negative molecule positively electrically charged; and the symbol ○ an electro-positive molecule charged negatively. The plus and minus signs when combined show light, and when separated they show electricity. The radiant matter from the negative pole (as in the cathode rays) may travel in straight lines perpendicularly to the surface of the radio-active substance.

radium are established as chemically elementary substances, they will lead all other known substances in their radiating power; other substances supposed to be elementary have been discovered by the method termed radiation analysis. F. Geisel has been able to produce the shadow of a hand on a phosphorescent screen eighteen inches distant from the radiant substance, and metallic plates $\frac{1}{16}$ of an inch thick have been pierced. The Becquerel radiations will produce ozone, and they

are probably capable of electrolysis in certain substances.

144. An explanation of radiant energy emanating from various substances may be given as follows: Under thermo-electricity it was shown how heat is absorbed, circulates as electricity, and is emitted as heat (§ 103). The principles of thermo-electricity are fundamentally the same as those underlying the radio-activity of certain substances. In Figure 65 there is represented a line of molecules which by the action of light are polarizing, being similar in this respect to high potentialed and delicately balanced molecules of specialized tissues (§ 155, 270) (Fig. 8). The exposure to light also creates a difference of potential in the parts of the substance. Each molecule or line of molecules assumes a positive and negative pole with differentiated polar fields; an analogous condition is found in the tetanized nerve. The vibrations of the molecules when started keep up a uniform rate, and the intermolecular ether, already polarized by the potential of the ponderable molecules, is split up, and the ether-atoms pass to the respective poles of the metal as in an induced coil. The particles of air or other matter at the poles are electrified by the respective polar charges, and are immediately repelled from their own poles and attracted toward the opposite, thus completing the circuit. When the charged particles meet, the charges neutralize and light waves are projected. There are therefore two forms of radiant energy—the charged particles and wave motion. Although exposure to light may be requisite to initiate the radiant action, it is afterwards kept up by the vibrating molecules. Moreover it supplies its own light which acts as a polarizing force. Furthermore this balance wheel of energy is energized

every time it is exposed to light, and perhaps by heat waves when in the dark.

The great essential to the possession of the property of transforming other energy into light is sensitiveness to molecular and mass polarization. The ether, instead of passing through the metal in the molecular state as heat, is split up, and the constituent atoms seek the respective poles of the metal. The vibratory frequencies of the molecules of these metals must be great, as no doubt they have the power of converting heat radiations into light. They must be also the very best conductors of electricity. Each molecule of the substance when exposed to a radiant energy whether as light or heat instantly polarizes and in so doing dissociates the ether of the radiations. In a tetanized nerve not only the ether is thus polarized, but ponderable matter may be also polarized as in electrolysis (§ 294), and this shows that fundamentally the property is general. The constituent of the molecule of a radio-active substance must have such a relative placement that they polarize and depolarize with the slightest intrinsic disturbance and with the slightest extrinsic stimulation. The potential of radio-activity is a *potential of placement of ultimate units.* The radio-active molecule is more easily polarized than the molecule of the magnet, but the former must have a larger immolecular neutralization when polarized, and consequently less polar potential (§ 69, 70).

Since this chapter was written the author has read an article by Professor J. J. Thomson, on "bodies smaller than atoms."* Thomson shows that the cathode rays are made up of atoms or "corpuscles" 1,000 times smaller than the hydrogen atom. It will be obvious to

* *Popular Science Monthly for August, 1901.*

any one who follows the reasoning in this work that the so-called corpuscles are primary condensations of ponderable matter (§ 19). It is interesting to know that in a tenuous condition 1,000 times greater than hydrogen there are atoms which are carriers of electricity, which means that unit matter has not been reached (§ 38). The Crookes tube, however, approaches a decrement in which carriers of electricity are absent. If the hydrogen atom is 1,000 times larger than primary condensations (§ 24) it will have a constituency equivalent to 3,000 ether atoms (§ 19).

The cathode rays consist of negatively electrified particles (§ 132) which are of constant mass independent of the kind of gas or electrode used. The particles are therefore the invariable constituents of all atoms or molecules. The most extraordinary fact demonstrated by experimentations made with vacuum tubes by Wien and Ewers, and with an incandescent wire by Thomson, is that positive electricity, "instead of being associated with a constant mass 1/1,000 of that of the hydrogen atom, is found to be always connected with a mass which is of the same order as that of an ordinary molecule, and which, moreover, varies with the nature of the gas in which the electrification is found."

We quote further from Thomson's article: "A very interesting case of the spontaneous emission of corpuscles is that of the radio-active substance radium, discovered by M. and Madame Curie. Radium gives out negatively electrified corpuscles which are deflected by a magnet. Becquerel has determined the ratio of the mass to the charge of the radium corpuscles, and finds it is the same as for the corpuscles in the cathode rays. The velocity of the radium corpuscles is, however, greater than any that has hitherto been observed

for either cathode or Lenard rays: being, as Becquerel found, as much as 2×10^{10} centimeters per second, or two-thirds the velocity of light. This enormous velocity explains why the corpuscles from radium are so very much more penetrating than the corpuscles from cathode or Lenard rays; the difference in this respect is very striking, for while the latter can only penetrate solids when they are beaten out into the thinnest films, the corpuscles from radium have been found by Curie to be able to penetrate a piece of glass three millimeters thick."

These interesting phenomena are easily explained on the basis of the fundamental principles already laid down. It has been shown that at certain temperatures oxygen will leave potassium and unite with carbon (§ 36). That is to say, the molecule of carbon dioxide can exist at a temperature in which the atoms of potassium carbonate dissociate. Now observe the difference between the total positivity (the number of positive units) of potassium carbonate and the total positivity of carbon dioxide. Is not the negative quality of an atom or molecule a determining factor in its maintenance in the gaseous state?

It has been pointed out that positive ether is characterized by a concentrativeness and negative ether by a diffusibility or tenuity, and the same may be said of electro-positive and electro-negative chemic elements (§ 39). From these and other considerations the following law may be enunciated: *That the size of a molecule in a gas is directly proportional to its negativities and inversely to its positivities.* As positivity tends towards solidity, a molecule having the degree of the positivity of hydrogen and the dimensions of oxygen assumes the solid state. Hydrogen atoms according

to their size should be placed in the higher parts of the earth's atmosphere, but their positivities place them at the earth's surface and unites them with the larger sized oxygen atoms. The molecule of oxygen, O_2, is larger than the molecule of water, H_2O. Is not the positivity of hydrogen, independently of its neutralizing power (§ 32), a factor in determining the fluidity of H_2O?

The Crookes tube is a world by itself and is free from environing influences. The residual molecules have to fill the space, and they assume proportional dimensions according to the above law. The molecules dissociate and reform, and the reconstruction embraces the constituent units of the atoms. They assume a certain relative size for molecules of positive potential to a certain definite size for those of negative potential. The reconstruction of the new molecules is not according to the law of affinities, as the interspaces are larger than the areas of attractions. The negative units leave the positive units as oxygen leaves potassium at a high temperature (§36, § 37), and the reconstruction accords with new conditions. The diffusibility of negative units allows them to maintain a relative large molecule, whilst the concentrativeness of positive units determines their breaking up into smaller groups in order to meet the conditions of tenuity. Thus there is a very small positive molecule, whilst the new negative combination is relatively large. In a general way the tube is filled with molecules of two sizes—condensations of different degrees. The relative sizes of the molecules in a vacuum tube seem to conform to the relative dimensions of oxygen and hydrogen molecules, modified by changed conditions of pressure; the difference in the relative sizes of positive and

negative molecules of gases being increased as the decrement is increased.

The minute positive condensation is electrified by the negative electric current and the larger negative condensation is electrified by the positive electric current. The smaller electrified body is the one that jumps the breach.

That certain metals give off minute atoms can be explained as follows: The metal-atom is electro-positive, that is, it has a constituency largely composed of positive units. Hence groups of units mainly positive are torn off by the negative current as primary condensations. On the other hand, the positive current cannot tear off negative groups or negative condensations, because the constituent negative units are held fast by the positivity of the metal-molecule. Under these conditions the positive current attaches itself to the negative oxygen of the air (§ 61), or the point of neutralization may be at the positive pole, as in a vacuum tube. Thus the negative current breaks off a minute chip from the metal-molecule at the positive pole, and carries it to the negative pole of the metal, where the charge on the particle neutralizes, and the particle being a sub-condensation immediately unites with the nearest metal-molecule, which passes it to the next in line, the metal resuming equilibrium. Obviously the Becquerel ray is similar to the cathode ray in being a minute positive particle charged negatively, the charge being convertible into light waves on neutralization. Odor may depend on radiating chips from larger molecules which by reciprocal action are regained by the dissociating molecules. Molecular dissociation in general is chipping molecules, and the hydrogen molecule may be designated as a chip.

I suggest to experimenters that they try the effect of having the cathode of a Crookes tube composed of a a radio-active substance. It is probable that the metal will furnish sub-condensations for the tube.

Radio-activity has two factors:

1. A delicate vibratory balance of the molecule. It is essential that the molecule be finely adjusted to its vibratory space. Mark the difference in metals as regards electric conduction. Silver and copper are elements of small inductive potentials and small induced fields, which evidently give them a molecular equipoise offering slight resistance to a vibratory stimulus.

2. A relative placement of ultimate units in the molecular construction favoring the dissociation of a group from the molecular positive pole. Mark the difference between the amounts of the electrolytic force requisite to the dissociation of different substances. Every time a molecule in the optic nerve vibrates in response to light there is dissociation, whilst other molecules resist the highest practicable temperature.

Radio-activity depends upon the property of transforming energy, a property which reduced to its fundamental principles is common to all matter. It is a manifestation of force in delicate equilibrium. The vibratory frequency of the metal-molecule, the minuteness of the dissociated particle, and the projectile energy are determinating factors of penetrating power. The projectile force depends upon (1) the inherent repulsion of negative units (the negative electric charge) as in the cathode rays; and (2) attraction between the negative and positive charges. The first may act independently of the second as in the cathode rays,

hence the radiant energy from the negative pole may travel in straight lines perpendicular to the surface of the radio-active substance.

Sound

145. For the purpose of showing the reciprocal relationship, in vibratory motion, between ponderable molecular matter, molecular ether and atomic ether; and also for the purpose of comparing certain physiologic phenomena with electric manifestations, reference is made here to some of the principles of sound vibrations.

Physically sound is known as a wave motion and consists of alternating condensations and rarefactions of molecules, of gases, liquids and solids—the conditions and not the molecules being propagated (Fig. 66).

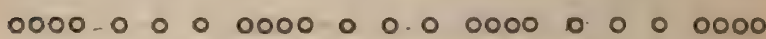


Fig. 66.
Alternate Condensation and Rarefaction of Molecules as Sound-waves.

That the motion of molecules will set up vibrations in the ether is proved by the sudden compression of gases being accompanied with the emission of light or

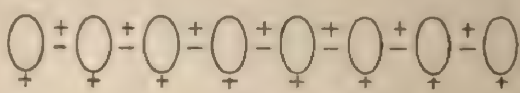


Fig. 67.
The spheres represent molecules of matter; ±, molecules of ether; +, positive electrification.

heat. By a study of the formulae (Figs. 67, 2, § 7) it will be seen that no impulse can be given to either the ponderable or ether molecules without a cor-

responding motion taking place in the other. This obviously follows from the impenetrability of ultimate units.

146. The principles of reciprocal transmutation of motory influences apply more distinctly to the ponderable molecule and atomic ether, the latter being adherent to the former. It is upon the principle of motory reciprocity that the telephone is constructed, a description of which is herewith given.

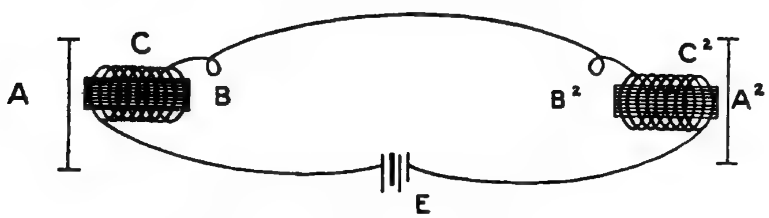


Fig. 68.
Representation of Section of Telephone.

In Fig. 68 A, A², represent diaphragms at transmitter and receiver ends of the telephone; B, B², bars of iron around which part of a circuit, C, C², is coiled, E being a battery. When a current flows, the iron bars are magnetized, and surrounding each of these is an induced field of intense electrification—ether polarization (§ 66) (Fig. 69).

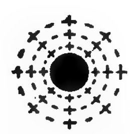


Fig. 69.
Cross-sectional Area of Circuit with Induced Fields of Polarized Ether.

147. When the diaphragm vibrates in response to the voice, the vibration is communicated to the polarized molecules in the induced electric field, and thence

to the magnetized iron, and to the molecules of the coil encircling the iron. Hence the polarized field of ether from its extreme elasticity is in a state of oscillation, as well as the atomic ether in this part of the current. The copper wire, the magnet, the air, and ether in the induced field, being polarizable or capable of assuming a condition of stress, have properties favorable to the interception and transmission of vibrations responsive to diaphragmatic movements.

The question presents: What is the character of the transformation occurring when sound vibrations pass from a medium such as air and enter media such as electric currents or nerve conductors? It is hardly conceivable that molecules, polarizing and depolarizing as those of a neurone, or of an electric circuit, would be subject to condensations and rarefactions as in air or solid bodies not associated with electric potentials. If that were the case electric currents could be dispensed with in the telephone and a simple wire employed. In an intense induced field created round a magnet, or in a solenoid, the vibrations are no doubt distortions of the field, depending on the elasticity of the polarized ether, and corresponding and responsive to the sound vibrations in the adjacent air—whose molecular fields are also distorted by the condensations; but within the circuit or neurone the vibrations must be different. The propagation, by electric circuits and neurones, of sound-vibrations received from other media, may be conceived as being accompanied by a *transformation from condensations and rarefactions to accelerations and retardations of molecular polarizations.* Thus the condensation-element of the sound wave will stimulate and hasten molecular vibration; on the other hand the rarefaction-element will inhibit or delay it. The accelera-

tions and inhibitions in turn are transformable to condensations and rarefactions in the proper medium. At the receiver end of the telephone the induced field around the magnet responds to the variations in the circuit, hence they are communicated to the air.

The author's conception of the passage of sound through a permanent magnet is that the medium will act as one vibratory unit, the polarized ether at the proximate pole, through continuity, communicating the sound to the polarized ether at the distal pole by a single vibration. The molecules being fixed, the magnet is potentially one vibratory element, and does not possess the property of wave motion (§ 245).

Conduction of sound by electric circuits is a subject of the utmost importance to electro-physiology, the axis-cylinder of nerves being polarizable bodies, and the telephone in many respects bearing resemblance to the auditory apparatus.

CHAPTER IX

Crystallization

148. When solidification takes place slowly, from solutions or from fused substances, the resulting solids may be in regular geometrical forms called crystals. The essential condition is that the smallest particles have free motion. In this case the attractions and repulsions enable them to arrange in symmetrical order. When solidification takes place heat escapes from the substances solidifying; and every liquid has a definite solidifying or crystallizing degree of temperature.

Crystalline bodies are non-isotropic in their expansion when heated. Thus Iceland spar expands parallel to its principal axis, but contracts at the same time in perpendicular directions. Very often two salts will crystallize together in molecular proportions, when they have only a partial and sometimes hardly any recognizable miscibility with each other. Water unites in molecular proportions with many substances to form crystals; and it is then called the *water of crystallization*. This property is not limited to water, as is shown by alcohol of crystallization, benzine of crystallization, etc. At certain temperatures of transformation salts containing water of crystallization are dehydrated.

149. When a liquid is cooling molecular ether is being emitted. There is thus an ether-movement throughout the whole body of the liquid towards its

surface, which brings the molecules into symmetrical lines. The process is in part similar to the polarization of a magnet. However in magnetization (§ 67) the polarization of the ultimate units is more complete and the molecules have greater polar potentials. When cooling takes place quickly the molecules are unable to arrange their poles in a symmetrical direction, and there is probably left more latent heat than is consistent with crystallization.

Fig. 70.
Molecules in Solution at a High Temperature.

Fig. 70 represents molecules of positive potential with uniformly induced polarized fields. The intermolecular space, outside of the induced fields, is occupied by free molecular ether representing the potential of heat. As the temperature of the liquid decreases, the intermolecular ether is emitted from its surfaces, and the dimen-

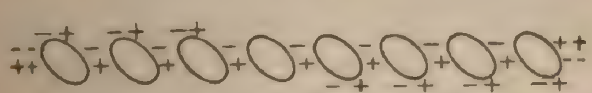


Fig. 71.
Molecules Polarizing and Heat being Emitted, Induced Fields Omitted.

sions of the intermolecular spaces are lessened. As the ether molecules travel toward the surface of the liquid body they pass through the induced fields of the ponderable molecules and consequently become polarized, and as they pass outward they drag the ponderable molecules into uniform line, which are also polarized.

Fig. 71, shows the polarizing movement, the polarized molecular fields being omitted. Fig. 72, shows molecules in condition of crystallization with sufficient intermolecular ether to allow light waves to pass through. The molecules are held in their relative position by their polar attractions and by the forces of their induced fields, which now meet, or approximate, approximation taking place on account of the decrease of the intermolecular ether. When a molecule is polarized, the molecular hemispheres are equipotential, and must have uniform polar directions. A crystallizing molecule therefore absorbs another molecule or molecules into its construction in order to round out the deficient hemisphere (§ 169). It is clear that the character of the absorbed molecules will vary as the character of the crystallizing molecules varies.

Fig. 72.
Molecules Polarized (Induced Fields Omitted), with a Residual Amount of Depolarized Ether.

150. The essential accompaniments of crystallization the (1) equipotential and symmetrical hemispheres in are polarizing molecules, with equipotential and symmetrical induced polar fields; (2) the absorption of other molecules into the molecular construction to enable the hemispheres to become equipotential when the polarizing molecule is spherically deficient; (3) on depolarizing the absorbed molecule or molecules are dissociated—dehydration.

A depolarized molecule has a uniformly environing (except when distorted) induced field according to the quality and quantity of its inductive potential (Fig. 70).

A polarized molecule, having its poles differentiated, has differentially polarized but equipotential and symmetrical polar induced fields (Fig. 73). During polarization the units of force at a pole of a molecule are neutralized intrinsically by the forces of the other hemisphere; or extrinsically in the polar induced area, or by the polar forces of a proximate molecule. The neutralization takes place according to the law of forces (§ 1). It is evident that during polarization the forces at the opposing poles of different molecules must be quantitatively equal in order to allow complete neutralization, hence additional molecules are absorbed into the molecular construction. The distinctive geometrical forms of crystals may be accounted for by

Fig. 73.
Polarized Molecules, Induced Fields Approximating.

supposing that the longitudinal lines of molecules being superimposed in tiers, the ponderable bodies of the molecules are adjusted to the induced fields of the adjoining layer. Thus the potentials of molecules determine the symmetrical forms of crystals.

Apparently, in some instances, crystals of a substance having induced molecular potential may form without associating molecules, but this is only apparent, as the substance may be its own associating material. Thus water alone forms crystals, but in doing so each molecule may associate with another molecule, the two molecules being reversely placed. Thus water crystallizes with one molecule of the water of crystallization. The principle of reverse placement of the constitu-

ents of a crystallized molecule is important in judging of the adaptability of associating material to its architectural placement in the molecular structure.

This subject has been considered here because the author believes that *crystallization is the great physical analogue of physiologic action*,* the physical and physiological phenomena having the principle of *molecular polarization* as a common basis. The physiological facts present wonderful analogies to their physical prototypes, and the differentiations are clearly marked as belonging to environing conditions.

* In articles entitled "From Ether to the Physiologic Unit," read before the Medical Society of the State of California, April 17th, 1902, and published in the *Occidental Medical Times*, San Francisco, September, 1902; and "The Physiologic Unit," published in the *Pacific Medical Journal*, August, 1902, the author advanced the theorem that crystallization is the great physical analogue of physiologic action, and presented supporting facts.

PART II

ELECTRO-PHYSIOLOGY

CHAPTER X

PROPERTIES OF LIVING MATTER

151. The following properties are possessed by so-called living matter:

Contractility. By this is meant the power of a substance to move and change its form by an intrinsic potential, in response to initiatory and external influence.

Irritability. A substance is said to have irritability when, in response to an irritant, chemic or physical changes take place, which are quantitatively greater than the value of the irritant. An irritant may be mechanic, chemic, thermal, electric, or physiologic.

Conductivity. When a portion of a substance is irritated and the substance is capable of conducting the irritation throughout its structural continuity, it is said to have the property of conductivity.

Elasticity. Elasticity is the property of a body which enables it to recover its form when the force which altered it ceases to act.

Distortion. When a body alters its shape under pressure it is said to be distorted.

152. The conception that living matter possesses certain distinctive properties implies that there is a fundamental difference between living and other matter. This is misleading. All matter, whether living or dead, organic or inorganic, can be reduced by analysis to chemically elementary substances, and it is probable that the chemic elements may be dissociated and the ultimate ether reached. It follows that all properties possessed by matter, however complex in character, when analyzed, are composed of the simple properties of the ultimate units—ether-atoms or their qualitative values—which are *attraction* and *repulsion*.

The distinctive properties of living organic substances will be found to depend on the *potential* of the molecule, and on *environing conditions* which allow the potential to be maintained, and at the same time do not disturb the exercise of its properties.

153. *Ether Changes*. All chemical action is accompanied by changes in the ether conditions of the molecules readjusted; a change in the molecular inductive potentials indicates a change in the amount of ether in the molecular induced fields. If the potential that causes the action is resident within the molecules—chemical affinity—ether is eliminated if the physical condition be not altered; if the potential is an outside force—heat, electricity, etc.—ether is absorbed into the molecular induced fields.

When there are changes in the physical state of matter from solid to liquid, or from liquid to gas, ether is absorbed, becoming intermolecular; if the reverse changes occur, ether is set free, manifesting itself as heat or as electricity. These changes may happen separately or conjointly, and they may assist or annul each other in the absorption or elimination of ether.

When ether is absorbed it becomes intermolecular, or under favorable conditions is separated into atoms and forms an electric charge or current (§ 43). If eliminated it may manifest itself as heat (§ 41—43); and again, if conditions are favorable, it may become atomic and an electric charge or current is effected. Furthermore, by electrolysis ions may be formed and polarized at the terminals of neurones. They have an increased inductive capacity, consequently there is absorption of ether. Throughout the processes of digestion and assimilation ether is absorbed or emitted by the molecular changes, according to whether they are anabolic or katabolic. In the animal tissues the organic molecule has reached its highest point of *potential*, from this onward it splits up and ether is freed, or the molecules may retain their potentials in the physical changes from solid to liquid, or liquid to gas.

In such a complex body as an animal organism, where in every cell and fiber of the system chemical change is constantly taking place in the building up and breaking down, ether changes are correspondingly produced. In the disintegrating process ether is evolved as heat and the temperature maintained. Furthermore, certain tissues of the animal organization are so constituted that at the point of elimination the ether atoms are kept apart, and being conducted along the channels offering least resistance they form *electrical currents*, or *charges in polarized tissues*, and these *induce other charges or currents*. Thus the body currents may be likened to wind currents on the earth's surface. How these conductors are charged and discharged, polarized and depolarized; how they are grouped, linked to and separated from one another; how they are brought under control of the main nerve

centers, and how they assist in performing the varied physiological functions in which they take part, have not been completely demonstrated.

154. *Potential, Polarization, and Induced Field.* To understand clearly the functions of living matter, it is essential that the fundamental principles, upon which physiologic action is based, should be known. Molecular potential, molecular polarization, and the molecular induced, magnetic, or electric field (§ 29, § 67), have been shown to be properties of matter, associated with, if not necessary to chemic, physical and electric action. The author believes that these principles are of *equal importance in the production of physiologic phenomena.*

155. *Potential.* All molecules have an inherent potential of attraction and repulsion, excepting only the molecule of ether (§ 19, § 24). Potential, however, varies according to the character of the opposing or neutralizing force (§ 27). Ponderable matter varies in potential from that of the stable compound that cannot be broken up by known chemic means, to that of a molecule in living organisms having many hundreds or thousands of chemic atoms, and trillions of units of positivities and negativities(§ 18).

Nuclein may be considered as a representative of molecular living matter. It is formulated thus: $C_{29}H_{49}N_9\ P_3\ O_{22}$. This molecule consists of 112 chemic atoms of positive and negative character, hydrogen being positive (§ 36), nitrogen, phosphorus and oxygen being negative, and carbon equatorial or slightly positive. According to the estimate of the author, the majority of the ether-units in the construction of the atoms of such a molecule are positive in character, there being about the same ratio of positive and negative units as possessed by the molecule of water (§ 36).

The number and character of the chemic atoms give the molecule a positive inductive potential, and a potential of concentrativeness (§ 27). It is probable that nuclein is the base or part of the base of a cell-unit, and is capable of being built up to a negative potential by an association of the ions carbon, hydrogen and oxygen (§ 160, § 177). It may be considered as representative of a class of potential-carriers: Loading oxygen in the lung; unloading it in the tissues; and reloading carbon dioxide, which is delivered at the primary port. This class of oxygen-carriers is made up of elements which are *potential-tenders* to nutritive molecules, the latter carrying insufficient oxygen for complete combustion. A proteid from hemoglobin taken from a dog has been formulated as follows: $C_{726}\ H_{1171}\ N_{194}\ O_{214}\ S_{3}$. Such a molecule is capable of carrying within its induced field 500 molecules of oxygen or about an equal number of carbon dioxide, if its inductive capacity is not disturbed by the presence of other material. Molecular inductive potential has been defined as the difference between the sum of the positivities and the sum of the negativities in the construction of the molecule, and this potential is represented in a surrounding induced field, and is equivalent to the active chemic potential. Inductive potential is quantitative and qualitative—large or small, positive or negative. When compared with the glucose molecules, $C_6H_{12}O_6$, nuclein has relatively less, although specifically more inductive, accompanied with larger concentrative potential, hence it is a more stable molecule because more evenly balanced in its positivities and negativities, and will resist dissociation by oxygen at a temperature at which glucose will dissociate. The glucose molecule has an inductive potential apparently equal to that of

four to five molecules of oxygen; the nuclein molecule may be equivalent to ten to twelve molecules of oxygen in inductive potential; and these values represent the relative capacities of the substances as potential-carriers. Glucose, however, at the temperature of the tissues is subject to combustion, while nuclein by its stable character resists combustion at normal temperatures.

156. *Polarization.* By polarization of molecules is meant that all their poles of a kind point in one direction. It is evident that a body having its molecules polarized will itself have poles, and that if such a body be a unit of a larger body, the latter also will have poles. The molecules, the unit bodies, and the larger body will have poles uniformly directed. When a molecule polarizes it assumes a spherical form with *equipotential hemispheres.* If the relative number of the molecule's constructive negativities and positivities prohibit the hemispheres from becoming equipotential on polarizing, it either imbibes molecules of polarization, as in the case of crystallization, etc. (§ 149), or it extrudes molecules of polarization, as in the case of segmentation, etc. The former may be called *associated molecules of polarization* and the latter *dissociated molecules of polarization.* The associated molecules when given off may be termed *dissociated molecules of depolarization.* It is evident that a histological element composed of polarizable units will be governed by the same laws as the polarization of molecules. Furthermore, larger bodies composed of such histological elements will be governed by the same laws, modified by such conditions as their structural forms demand.

157. *Induced Field.* Under *Induction* the induced electric, or magnetic potential has been explained (§ 29,

§ 66, § 67). Two facts in connection with an induced field are particularly emphasized: First, that *molecules coming within the induced sphere are polarized, or have their inductive potentials neutralized by the primary potential;* and, second, that *polarization of a molecule is a step towards dissociation of its atoms.* Therefore polarization within the induced field is a potential which enables certain chemic combinations to be consummated which otherwise could not occur.

A B

Fig. 74.

A. Positively electrified body with induced field; electro-positive molecule of ponderable matter with its free or vibratory space; a molecule of strychnia; an organic molecule such as nuclein; the sperm-centrosome. B. Negatively electrified body with induced field; electro-negative molecule of ponderable matter with its free or vibratory space; a nucleolus with its induced field—the nucleus; the anisotropic substance with its induced field—the isotropic substance; a molecule of chloroform; the germ-nucleolus. As represented on the inner spheres of the figures the potentials when electric consist of ether units placed on insulated bodies; the potentials when molecular consist of partially free ether units in the molecular construction. The plus and minus signs of the outer spheres, or induced fields, show polarization of ponderable or ether molecules. The polarization can be demonstrated in the induced fields of electric potentials.

The induced fields of molecules play an important part in physiologic action. It will be seen that the action of enzymes and of certain medicinal agents, as well as the phenomena of karyokinesis, are only explainable on the assumption of their existence. *The induction in the field of a molecule varies with the potential of the molecule* (§ 65, § 67, § 82).

158. *Chemic Laws.* A law of the greatest importance in tissue metamorphosis may be formulated as follows: *Molecules tend to reconstruct under a lower potential.* That is to say, molecules tend to break up and reform under simpler forms with less chemic potential, energy being evolved equal to the difference of the potential of the old and the new molecules. The atoms in the newly constructed molecules are exactly the same as the atoms in the disintegrated molecules, but their attractions have been more fully neutralized, therefore they have less potential, and less induced potential in their fields—less ether polarized in the fields. It is from the induced field that energy—polarized ether—is set free (§ 42). This law explains certain *katabolic* changes.

Another law of equal importance with the above is that *energy seeks the course of least resistance.* Thus ether as energy, set free under certain conditions, will diffuse as heat, which means that it enlarges the intermolecular spaces until an equilibrium between ponderable matter and ether is attained. But suppose that there is great *resistance to its diffusibility.* Then it must alter local conditions and find room for occupancy. By converting a greater number of molecules into a less number with increased total inductive potential, the ether is polarized in the molecular induced fields (§ 22). In the polarized state ether occupies less space, and thus energy is stored, and space is economized (§ 22). In the rearrangement the molecules have more pronounced positive or negative potentials.

Again, suppose that in organized tissue offering great resistance to the diffusibility of heat, and also having an unyielding rigidity, there are set free by

nerve action certain ions from molecules of high potential. These ions have a tendency to form simple compounds, but by doing this they set free energy the radiation of which the conditions of pressure resist. In this case certain ions with their potentials are forced into the construction of other molecules (§ 209). It is obvious that, under the conditions mentioned, *anabolism* results.

159. *Molecular Equilibrium.* The equilibrium of matter and force in relation to space has already been referred to (§ 24, § 20, § 22). Molecules according to their inductive potential are surrounded by induced fields, and the whole has a definite spacial relationship, maintained by the molecular potential and modified by extrinsic pressure and temperature. A molecule of large dimensions, of large inductive potential, and corresponding induced field, will have within its field molecules of opposite potential. There is an attraction between these similar to chemic affinity, but *reactions will not take place if the sequent energy is resisted by a greater extrinsic force.* Chemic reaction between the molecule and the material in its induced fields would disturb the *molecular spacial equilibrium.* Manifestations of readjustment of molecular equilibrium are seen in a vacuum tube (§ 135—138), in the retort (§ 39), in plant anabolism (§ 203), in a compressed gas when heat is applied (§ 22), and in the galvanic cell (§ 41). From these it is seen that the molecular equilibrium has the following factors: The potentials of the molecule; its induced field; temperature and extrinsic pressure; and it is obvious that a readjustment results from a modification of any of these factors.

If by extrinsic pressure there is forced into a molecular space another molecule of perhaps smaller dimen-

sions but of similar quality as the principal molecule, these molecules will unite in order to maintain the molecular spacial equilibrium. The smaller molecule will pass by material of opposite quality, if present in the induced field of the larger molecule, because by chemically uniting with such there would be set free energy the radiation of which would be resisted by the extrinsic force. This form of anabolism is shown in the conversion of a molecule of starch into a molecule of sugar by the addition of a molecule of water, both of which are positive in quality; and by the addition of a nutritional molecule, H_2CO_3, to the physiologic unit, both of which are negative in quality. Fundamentally these forms of anabolism are the same. The processes represented by sugar, starch, etc., may be considered as representing vegetable anabolism, and is positive in the character of its potential; on the other hand, that which takes place in the animal cell or unit is negative in quality; the one is the coefficient of the other in a grand equilibrium.

A large number of physiologic facts has been hitherto incapable of satisfactory explanation. The author believes that a very large majority of physiologic problems will be satisfactorily solved with the aid of the simple principles above enunciated. Obviously a clear understanding of their import is imperative.

The Molecular Concept of the Physiologic Unit. As molecules vary in the amount of ponderable matter, and as they have impenetrable constituent units, they must vary in dimensions. The molecule of H_2SO_4 must have greater dimensions than those of H_2 and O_2, the constituents of the latter being represented in the construction of the former. The hydrogen molecule when broken up by decrement of pressure has as a

resultant a molecule 1,000 times smaller. This probably approaches the limit of dissociation. What is the limit of association? As dissociation rests on decrement of pressure, so association must rest on increase of pressure; although the qualities of positivity and negativity are also important factors in the differential dimensions. Under certain degrees of pressure and ether-energy—heat—molecules may be built up to an indefinite maximum number of chemic atoms, each atom being a group of units which, as a group, has no distinct entity in the molecular construction, the immolecular units being in absolute contact, and more or less mutually neutralized. Thus, physiologists have estimated that some molecules contain 2,000 chemic atoms. It is clear that the limit to the size of the molecule is indefinite, depending on the equilibrium of matter, and it is possible that under physiologic conditions a molecule may exist which can be seen and examined by means of the microscope, or even handled as an ordinary mass.

Bearing in mind that a molecule is the physical unit; that it is composed of an indefinite number of ether-units, and varies in the relative proportions of positivities and negativities; that its potential is represented by induction in an environing polarized field; that it has the property of assuming differential poles; and that within its construction there are no units, or groups of units—chemic atoms—which can be characterized as a molecule or sub-molecule, then, the concept that the physiologic unit is a molecule can be formulated.

That the nucleoli and centrosomata (§ 242) of animal cells, the anisotropic substance of muscles, the analogous unit in conducting nerve tissue, and various unit-bodies within the nuclei and cytoplasm of cells,

are molecules of inductive negative potential, having all the properties of the physical unit, is readily conceivable when the above definition of a molecule is accepted.

If it can be shown that the physiologic unit is surrounded by an induced field, the molecular condition of the unit is proven. Under ordinary conditions of pressure and temperature a mass, being composed of molecules, has no pronounced induced field, as the inductive potential of each molecule is represented in its own induced field (§ 43, § 159, § 245). It follows that a mass is a body composed of molecules, but it is possible that there are molecules which are larger than some masses.

In the induced field of small molecules ether is the polarized element, as no other is so molecularly minute as to be capable of filling the intermolecular spaces. In the induced fields of large molecules, and in those of electrically charged masses, ponderable molecules are polarized. Consequently there are found in the induced field—the isotropic substance—of the anisotropic molecule of the muscle, and in the induced fields —nuclei—of all nucleoli, molecules of ponderable matter, which are polarized, or whose potentials are neutralized, by the inductive potential of the primary force resident in these bodies. Furthermore, molecules within induced fields have their own induced fields within which smaller molecules are polarized, or potentially neutralized by the larger molecule, and this order progresses until ether is the only element intermolecularly placed (§ 243).

The intimate workings of the animal cell can only be understood by bearing in mind that there is a mutual repulsion between negative potentials, and an

attraction between negative and positive potentials (§ 29, Fig. 5), and that sensitive movable particles imbedded in semi-fluid plasma will manifest properties depending upon the laws of attraction and repulsion, without reciprocal dissociation. When ponderable molecules are small the intermolecular spaces are filled with ether. Larger molecules have within their fields ponderable matter in the main of opposite quality. Hence negative units have an alkaline serum, and within the serum positive molecules carry negative matter. Hence any negative molecule may be a carrier of positive matter, as the alkalies; and any positive molecule may carry negative matter, such as oxygen, without chemic union or chemic disturbance. According to the laws of attraction and repulsion, each negative potential has a tendency to surround itself with elements of positive potential (the converse being also true), consequently there are negative physiologic units surrounded by positive plasma, and consequently there are manifested evidences of negative bodies mutually repelling. The attraction referred to, between the positive and negative bodies or molecules, is the same in kind as chemic affinity, differing only in degree—an attraction which brings the bodies in proximation without reciprocal interchange of atoms (chemotropism). Important factors in the prevention of chemic reactions taking place between these elements of opposite quality are resistance to the radiation of heat which results from their union, and the degrees of temperature.

Molecules as *potential carriers* may be divided into two great classes: (1) Molecules raised in potential by adding other molecules of the same quality (ions), the union being chemically synthetic, and accomplished

by extrinsic pressure; the potential elements being unloaded at a distant part of the body; (2) molecules which attract to their induced fields smaller molecules of opposite quality, no reciprocal chemical action then taking place; but at a distant point and under different conditions chemical reactions between the potential carriers and the molecular elements of the induced fields occur. The first class exemplifies the function of the thyroid and other glands, and the latter the absorption of oxygen in the lung. Clearly the latter class of molecules contains all the essential elements of combustion, although for complete combustion potential-tenders are essential. Like the elements in an electric cell, they need only lessened extrinsic resistance or a slight rise of temperature (heat of dissociation) to chemically react and to emit energy (§ 41.)

The potential of nucleoli and of most physiologic units is of negative quality. The fact of the stimulated or leading off point of a muscle becoming negative is only explainable on the hypothesis of the stimulated unit turning its positive pole towards a negative mass (§ 186—190); the experiment by Lott (§ 237) proves that the spermatozoon seeks the electric positive pole when not electrically charged, thus showing its mass to be electro-negative; and with the hypothesis that nerve tissue is negative electro-neural facts are consistent.

The molecular conception of the physiologic unit renders possible the explanation of muscular, neural, gland-cell and electric cell action. The details of the phenomena of fecundation, cell-division, cell-movements, and osmosis fully accord with the fundamental properties of the molecule and physiologic unit as defined in this work. It may be practically impossible

to ascertain the exact chemistry of the unit. However, it may be assumed that it is composed of hydrogen, carbon, phosphorus, nitrogen and oxygen. Sulphur is probably an element of the insulating tissues. The conception of the unit being molecular enables us to formulate the following law: *That the physiologic unit at rest is in the electric state, with a uniform induced field; and that in action it is in the magnetic state, with differentiated poles, and differentiated induced polar fields* (Figs. 1, 75).

Fig. 75.
Physiologic Units at Rest and in Action. The Units at Rest are shown as being Laterally Compressed.

The evidence is conclusive that function is based upon the polarization of physiologic units, and that these units are molecular. The initiatory unit polarizes with the positive pole towards the negative mass of the structure, and gives a negative leading off point to the functional wave. These facts and conclusions furnish a key to the solution of the problems of stimulation or inhibition of nerve conductivity by initiatory excitants. Electric and chemic influence on the functional activity of physiologic units, in general, is formulated thus:

1. Stimulation:

(1) Physiologic units are stimulated to a normal polarization by kinetic negative potentials, as manifested by kathodal applications of electric currents.

(2) They are stimulated to a normal polarization by static positive potentials, electric or chemic: *a.* By the positive charge from a static machine (§ 313). *b.* By alkaline solutions as shown by their action on spermatozoa (§ 237).

2. Inhibition:

(1) Physiologic units are inhibited by kinetic positive potentials, as manifested by anodal applications of electric currents.

(2) They are inhibited by static negative potentials, electric or chemic: *a.* By the negative charge of a static machine. *b.* By acid solutions, as shown by their action on spermatozoa.

Definition. In this work the term *physiologic unit* is applied to unit-bodies (considered molecular) engaged in functional activities. Thus nucleoli and centrosomata, the chromosome units or molecules of nuclei and similar protoplasmic bodies in cytoplasm, the anisotropic substance of muscles and an analogous nerve-unit, are referred to as physiologic units or physiologic molecules, or muscle, nerve, or gland-cell units or molecules; each being regarded as the seat of functional potential, as consisting of one molecule and as having the common property of polarization the fundamental principle of function. The evidence that the anisotropic substance and centrosome are molecules is clearly conclusive, associated facts of muscular action and those of cell-segmentation supporting the molecular conception. Experimental facts connected with nerve, gland and other functions point to there being a common fundamental basis for all functions. Thus if the molecular character of a unit engaged in a special function is proved it should lead to a general acceptation of all physiologic units being molecular; and this more

readily must obtain in as much as physiologic facts are in no way contradictory to, but, on the other hand, are supporters of, and are explainable by the general application of the concept. In addition, that the conception of the character of the molecule is physical in origin, and supported in general by physical facts, are strong evidences of its physiologic truth—it is not a theory concocted to explain a fact, or group of facts, but is sequential to the fundamental law of force, and in turn forms the basis of a grand generalization. The applicability of the term *unit* to these molecular bodies is distinct, and is founded on the fact of their being the smallest structural divisions which retain the functional principle. The term cannot be applied to nerve or muscle fibrils, because they can be divided and yet retain functional activities.

The physiologic unit is surrounded by an induced field, and in a broad sense the term should comprise this field as the term molecule comprises its intermolecular space. The interspaces of units are filled with material essential to function; as, for instance, the isotropic substance possesses elements necessary to the property of contractility. In this broader sense physiologists have provided the term *sarcomere*, which denotes the muscle-unit inclusive of its induced field. That there is a *neuromere* is rendered probable by the identity of electric reactions of nerve and muscle. The lessened pressure by the absence of an elastic sheath in nerve structure seems to be the chief factor in the production of a nerve molecule so minute as to be beyond microscopic observation.

CHAPTER XI

METABOLISM

160. It has been shown (§ 41—43) that the polarization of the ether molecule is a step towards disintegration, and the same may be said of the polarization of all molecules (§ 51—54). When certain complex molecules of living matter polarize, as during muscle contraction or nerve conduction, some of their atoms are dissociated. Physiologic facts lead us to believe that in the metabolism of conducting and contracting tissues the segregated atoms consist of oxygen, carbon and hydrogen. In Fig. 76 the spheres represent physiologic units or molecules; the first sphere representing a molecule depolarizing, the other molecules polarized or tetanized. The minus sign represents oxygen, and the plus sign either carbon or hydrogen, or both. When depolarization takes place the positive unites with the negative element, and CO_2 and H_2O are formed. That these are the elements of waste is evidenced by the acid reaction obtained after a period of nerve and muscle-action; by the character of the con-

Fig. 76.
Representing Molecular Units Polarized and Depolarizing.

stituents of the cell; and by their probable arrangement during polarization (Fig. 1, 76).

Placing the atoms in order from their electro-negative to the electro-positive quality the physiological unit has a formula as follows: $-O_nN_nP_nC_nH_n+$. When polarized the most electro-negative will constitute the negative pole of the unit, and the most electro-positive the positive pole. During polarization these elements

Fig. 77.

A Gangleon cell from the anterior horn of the spinal cord, showing arrangement of Nissl granules and ramification of the dendrites (*after Gordinier*).

are held fast at their respective poles. Now the hydrogen atom at the positive pole is attracted towards the equator of its own molecule and towards the negative pole of the adjoining molecule, according to the great law that forces react in inverse proportion to the square of distance asunder. Clearly the hydrogen atom will leave its molecular situation and dissociate at the mo-

ment of depolarization. The same may be said of its fellow the carbon atom, although its attractions are less positive. The oxygen atom at the negative pole will dissociate also for the same reasons. The proportionate numbers of these atoms dissociating from their respective poles will be according to their chemic valencies, these being the potentials which govern polar attraction. Hence there are hydrogen, carbon and oxygen, in chemic proportions, in the nascent state, as a result of each vibration or polarization of the physiologic unit, and hence these constitute the waste elements. Furthermore, if these are the elements of waste *they in some form must be the elements of nutrition.*

The ether changes are as follows: On molecular polarization taking place, ether is also polarized, that is, polarization causes more intense and differentiated polar induced fields, the ponderable molecules assuming the condition of magnetization (§ 1, § 69). During the depolarizing act ions are formed with increased potentials, increased induced fields, and increased polarization of ether. When depolarization takes place molecules of simpler construction are formed and ether is set free from the induced fields of the ions uniting. This ether may radiate as heat, or under favorable conditions may form an electric current (§ 41—43).

The loss of oxygen, carbon and hydrogen lessens the potential of the physiologic unit and represents the waste that occurs during action. It is the katabolic change that results from the physiologic action of nerve and muscle, and the similar action taking place in gland-cells (§ 203), and other physiologic units.

161. After losing some of its atoms, can a molecule of high potential retain its structural position, and recover its lost potential by absorbing elements similar

to those lost? The fact that it requires a continuity of structure for nerve-conductivity, which would be destroyed by a line of broken-down molecules, is evidence of the fact that the molecular base is maintained, and that recuperation is effected by absorption from neighboring molecules.

Fig. 78.

Two motor cells from lumbar region of spinal cord of dog. A, from the fresh dog: 1, pale nucleus; 2, dark Nissl spindles; 3, bundles of nerve fibrils B, from the fatigued dog: 4, dark shriveled nucleus; 5, pale spindles. (*After Mann.*)

It has been stated (§ 8) that the surface of an electrified conductor is equipotential, and it is plain that the surface of liquids are physically equipotential. A line of molecules of high potential, finely adjusted, as must be the case in the conducting filament of a nerve, will be *chemically and physiologically equipotential.* This accords with the law that molecules tend

to reform under a lower potential (§ 41), and to the physical fact that water seeks a lower level.

162. According to Schultze, as the axon enters the cell it splits up into fine fibrillæ, which pass through the cell and are continuous with the dendrites. Surrounding these fibrillæ and within the cell is a mass of protoplasm, proteids and hydro-carbons. After a period of rest, there is established between the molecules of the conducting fibrillæ and those of the pro toplas mic material a physiologic equilibrium. During nerve action the conducting molecules lose part of their oxygen, carbon and hydrogen, which lowers the molecular potential of the fibrillæ and disturbs the equilibrium. To re-establish the equilibrium there must be a movement of carbon, oxygen and hydrogen elements —H_2 CO_3—from the protoplasm of the cell, along the nerve fibril. By this anabolic process the potential of the fibril is regained at the expense of contemporary katabolism of the protoplasm of the cell (Figs. 78, 115). There must, however, be extrinsic pressure as a factor in the re-establishment of the equilibrium, as the nerve units and hydrogen carbonate are similar in potential, both being negative.

In the Daniell cell a *displacement-movement* takes place in order to establish a chemically equipotential surface, as shown in the following formula:

$$\mathrm{Zn}\ \begin{array}{c}\mathrm{Zn\ Zn\ Zn\ Zn}\\ \mathrm{SO_4SO_4SO_4SO_4}\end{array} \left| \begin{array}{c}\mathrm{Cu\ Cu\ Cu\ Cu}\\ \mathrm{SO_4SO_4SO_4SO_4}\end{array}\right.\ \mathrm{Cu}$$

Zn represent the zinc plate; $ZnSO_4$ represent a solution of zinc sulphate; $CuSO_4$ represent a solution of copper sulphate. These solutions are divided by a porous partition. Cu represent the copper plate.

The explanation of the formula is as follows: The zinc plate is more positive than the copper plate, consequently the negative radical, SO_4, has a tendency to leave the copper and unite with the zinc, thus setting free energy. The difference of potential is not sufficient to cause chemic reaction unless a way is provided for the energy—ether from induced fields—to escape with slight resistance. The conducting circuit provides the necessary path and the energy escapes as an electric current. Under these conditions there is a general movement of the radicals, SO_4, by displacement, towards and to unite with the zinc, whilst copper is deposited on the copper plate.

If a conducting nerve fibril be supplied with nutrition from its ganglionic cell, the dissociated carbon, hydrogen and oxygen of the protoplasmic molecules of high potential, under the osmotic pressure of the blood and the heat produced by the combustion of the proteids and hydro-carbons, will move along a line of molecules of lower potential, and, by anabolism, will add to the stored energy of the molecules of lessened potency in the conducting fibril.

The protoplasm of the cell, on giving up elements to the fibrils, further disintegrates into excrementitious substances, a new set of molecules being supplied by the blood (§ 239). The cell is thus maintained as a store-house of high potential molecules—proteids and hydro-carbons with oxygen in their induced fields.

The metabolism of the muscular fibrilla takes place on the same principles as the metabolism of the nerve, only the nutrition is derived from the combustion of elements in the surrounding plasma. The nerve-filament also may derive nutrition from the plasma in which its conducting elements are imbedded. In the

displacement-action of the Daniell cell the principle of chemic equipotential surfaces is maintained, viz.: that molecules tend towards reconstruction at lower potentials. In the nutrition of a nerve fibril there is also the principle of equipotential surfaces, but the potential is built up, the process being anabolic, *i. e.*, the molecule of hydrogen carbonate of slight negative potential, is forced by displacement along the line of molecules—the nerve fibril—also having a potential of negative quality, and by pressure the smaller molecule is forced into the construction of the larger molecule or physiologic unit (§ 159).

163. As the physiologic unit takes on certain elements with a gain of potential, and gives them off as waste with a loss of potential, and as there has been work done, the inherent potential of the waste elements must be greater than that of the nutritive elements. The work done by the unit must be equal to the difference of the potential of the nutritive and the potential of waste elements. The metabolic changes involved must be molecular and *must be accomplished by a molecule*. No other conclusion can be arrived at. The pressure within the cell has two factors: (1) The high potential of the molecules of nutrition seeking a lower potential, and (2) the osmotic pressure of the blood. The transformation of energy may be stated thus: Work done by extrinsic pressure increases the potential of the unit by adding a molecule to the unit, the potential of the physiologic unit and the nutritive molecule being of negative quality. The increased potential of the unit may be termed a potential of concentrativeness. It is similar to the potential of a gas gained by compression. The potential of pressure is converted into a potential of concentrativeness and takes place during the rest of

the cell or unit. When the unit polarizes the potential of concentrativeness is transformed into a potential of diffusibility as represented in the ions separated at their respective poles. The three potentials, *extrinsic pressure, concentrativeness, and diffusibility*, must be quantitatively equal. The transformation of energy traced further shows differentiation. In muscle and nerve the ions combine and form simple compounds, the energy diffusing as heat. In the glands the ions perform an important anabolic function. Specifically, by extrinsic pressure derived from katabolism and blood pressure, the physiologic unit during rest takes on hydrogen carbonate, H_2CO_3, and during action gives off ions of oxygen, carbon and hydrogen. Externally, if work has been done, as lifting a body by muscular contraction, the body has gained in potential by being removed from the center of gravity, whilst a column of air has lost in potential by being placed nearer the center of gravity. The balance is complete, within and without.

The physiologic unit may be constructed in a somewhat similar manner to a salt, for instance an alkaloidal phospho-carbonate; the base being made up of oxygen, nitrogen, carbon, and hydrogen, with perhaps phosphorus, in such relative proportions to give it a positive potential. It may be a compound of nuclein. The acid radical may contain phosphorus, carbon and oxygen in sufficient proportions to give the whole unit a slight negative potential. These—the basic and acid radicals—will constitute the permanent part of the unit body, the unstable elements being oxygen, carbon and hydrogen in the relative proportions contained in hydrogen carbonate, and forming the nutritive and waste elements of physiologic action. Thus after a period of

rest the unit is increased in potential of negative quality, and after a period of action it is reduced in negative potential and approaches neutrality, or potential exhaustion. Complete exhaustion of a nerve-unit, however, must embrace the stored energy in the ganglionic cell of the neurone. The nutritive and waste processes taking place in an ultimate physiologic unit have an analogue in metabolism of starch. Thus a starch molecule, being of positive potential, is made more positive by the addition of a molecule of water and becomes a molecule of sugar. The sugar molecule is dehydrated and deposited in the liver as glycogen, to be again converted into glucose at the proper period. We have only to give the molecule of starch a permanent placement, and allow it to take on and give off water, to have an analogous metabolic process to that which takes place when the physiologic unit functionates and produces waste, and is again built up during rest.

It is generally accepted by physiologists that within the lung CO_2 leaves the blood and mixes with the air, concurrently with O_2 leaving the air and mixing with the blood. This is impossible either by the laws of gravity or osmosis, as both carbon dioxide and oxygen are negative and the former is heavier than the latter. If it be granted that the negative pole of the body-currents in the lung points outward and the positive pole inward, towards the blood, it will be seen that what takes place is as follows: Carbon, being positive or equatorial will pass outward by leaving its oxygen in the blood and uniting with oxygen in the air, thus seeking the negative pole, and thus setting free oxygen in the blood. Even if equatorial carbon may be drawn to the negative pole, by its passive potential (§ 36), in

the presence of oxygen. Oxygen in the air, seeking the positive pole, together with the oxygen set free by the elimination of carbon, constitute the free oxygen acquired by the blood through respiration. Water, being positive, seeks the negative pole and saturates the air within the lung. What takes place during the nutrition of the tissues is a reaction between electro-positive molecules of high potential, such as hydro-carbons and proteids, etc., and the electro-negative molecules of oxygen absorbed through respiration and carried in the induced fields of the former. If a chemical reaction occurred in the lung between oxygen and the positive elements of the blood the lung would be consumed by the heat evolved. The lowered temperature of the blood in the lung is probably the chief factor in preventing chemical union. Oxygen is therefore held in solution in the blood, that is, it is attracted by elements of opposite potential, as in diffusion or osmosis, and without chemic union, consequently it is carried to all parts of the body where under favorable conditions there is combustion between the potential-carrier and its load, part of the disintegrants being impressed into the physiologic units of the tissues as nutriment. Thus a molecule of glucose has an inductive capacity as a potential-carrier equal to four molecules of oxygen, and the latter remain in the induced field of the glucose molecule until favorable conditions occur for chemic union. These conditions are found in the tissues when there is a rise of temperature following their physiologic actions, and when a means is provided for the disposal of the disintegrants by lowered potential of physiologic units. One molecule of glucose, and its load of oxygen with a re-enforcement from a nutritive-tender, furnish six nutritive molecules of hydrogen

carbonate. Thus within the cell, and surrounding the ultimate fibril, and within the induced fields of all units, are the essentials of combustion, positive and negative elements—molecules of high concentrative potentials having in their induced fields oxygen in quantities equivalent, or nearly equivalent, to the physiologic nutriment values of the positive molecules. Some of the oxygen necessary for combustion may be carried by such elements as nuclein, globulins, etc., which are sufficiently stable to resist combustion; thus whilst a molecule of sugar is completely oxidized in the tissues, part of the oxygen may be derived from more stable oxygen-carriers, which remain in the blood, and become carbon dioxide (also electro-negative) carriers in the venous circulation. Then a molecule of sugar, including its load of oxygen (that is to say, four molecules of oxygen), would be electro-positive, a quality essential to its being attracted by negative tissues.

Blood

164. When blood is exposed to the action of the galvanic current by direct contact with the electrodes, coagulation takes place, which is physically different at the two poles. The clot at the positive pole or electrode is comparatively small in size, dark in color, and hard in consistence. It firmly adheres to the electrode, which it oxidizes if the electrode consists of oxidizable material. The clot at the negative is comparatively large, soft, and of a yellowish color. It does not adhere to the electrode, and bubbles of hydrogen gas cause a froth.

The production of coagulation of blood is slow, requiring some time to effect it. It also requires a de-

cided amount of current—100 to 250 milliamperes—and is aided by lessening the circulatory blood pressure. Experiments tend to prove that the passing of the galvanic current through the blood increases the amount of ozone—some part of the electrical potential is converted into chemical potential as existing in ozone (§ 161). The action is similar to that of electrolysis, only the oxygen ion, instead of being carried to the positive pole, is fixed in an adjoining molecule.

The differential polar action of the current on the blood depends on water being driven by induction from the positive to the negative pole, thus producing more fluidity at the cathode. The electrolytic results of acids at the anode, and alkalies at the cathode, do not appear to have any bearing on the character of the clot. It is well known that electrolysis is produced by a small current, whereas a large amperage is required to produce coagulation of the blood. The ions collect on the surface of the electrode and their action does not extend into the clot.

165. The author advances the following theory to account for coagulation. The blood coagulates in the vicinity of the electrodes owing to the concentration of the current at these points.

The cathodal clot is large because the negative current possesses the property of diffusibility to a greater degree than the positive (§ 39), and is less dense because of water collecting at the negative (§ 61).

In the blood there exists certain soluble proteids of the globulin class—paraglobulin and fibrinogen. They coagulate on heating. When these globulins are brought under the influence of a strong galvanic current they are polarized. In the act of polarizing they take up part of the blood serum, hence the supposition that

another material is produced which has been called fibrin. The imbibition of blood serum by the globulins is analogous to the absorption of water during crystallization—water of crystallization (§ 148, § 149). It is also analogous if not identical with the imbibition of fluid by the anisotropic substance of the muscle during contraction (§ 184). The polar attractions and the incorporation of fluid into their structure produce solidity of the globulin substance.

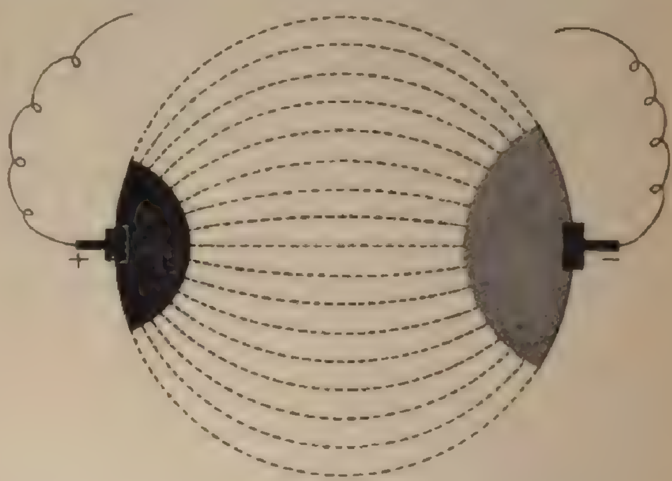


Fig. 79.
Showing the Different Degrees of Blood-clotting at the Galvanic Poles.

166. *Coagulation of Blood.* When blood is shed it remains fluid for a few minutes, then becomes viscous, and setting into a soft jelly it quickly assumes a firm consistence, so that the vessel can be inverted without spilling. The coagulum becomes still more compact and separates into the blood serum and a hard clot. The essential part of the clot has been called fibrin, which forms an exceedingly fine network of delicate threads permeating the whole mass. A drop of blood

placed on a slide and allowed to coagulate will show these delicate threads of fibrin.

It is found that the blood from a horse or terrapin, which clots slowly, can be prevented from coagulating by being surrounded by ice. A solution of certain neutral salts, such as sulphate of magnesium, will prevent clotting of blood. The action of albumose solution when injected into the circulation will retard coagulation. A solution of potassium and of sodium oxalate mixed with freshly drawn blood, sufficient to make a total strength of 0.1 per cent, will prevent coagulation. An addition of water will not produce clotting in the latter case, but solutions of calcium salts will quickly effect coagulation. It is supposed that the presence of soluble calcium salts and a fibrin ferment is essential to the coagulation of blood. A solution of pure fibrinogen may be kept at an ordinary temperature without coagulating, until putrefaction begins; the addition of a water-washed fibrin clot or a little blood serum causes it to immediately coagulate. Beating with a glass rod coagulates blood; but if the rod is oiled coagulation does not occur.

Rigor mortis may be characterized as a clotting of the muscle plasma, differing from blood clotting in as much as it is produced by myosin instead of fibrin. Myosin is a proteid and is classed with the globulin family, and has many analogies with fibrin. Myosinogen is an analogue of fibrinogen. The globulins of the vegetable cells have been obtained in well defined crystalline form.

167. The common principle, upon which these widely different phenomena rest, appears to be polarization, a fundamental property of all matter. Polarization in this sense means that molecules, acquiring differential

poles, have their positive poles uniformly pointing in one direction, and the negative in the opposite, as shown in Fig. 80.

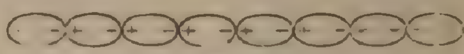


Fig. 80.
Showing the Polarization of Coagulation.

Between coagulation of blood and crystallization there is a marked resemblance. In both cooling has to take place slowly, for if the blood of certain animals is cooled by being placed on ice, coagulation is prevented. The polarizable material during coagulation or crystallization absorbs water or calcium salts. The absorption is prevented in the case of blood by certain salts of strong affinities.

168. When blood-molecules are polarized and there are still free spaces between adjoining poles, the mass constitutes a crystal (Fig. 84). When the molecule fills the whole free molecular path, coagulation is said to have taken place (Figs. 80, 83). Thus some of the proteids form crystals. When a molecule is evenly balanced in its positivities and negativities it will crystallize or coagulate without additional atoms, but when there is a preponderating potential as represented by positive or by negative atoms in the molecular construction polarization by dividing the atoms into hemispheres disturbs the constructive equilibrium of the molecular body. To round out the defective hemisphere, and at the same time to equalize its polar potentials, an additional molecule or molecules are required. We have named these *associating molecules of polarization.* They have been called water, alcohol, benzine, etc., of crystallization, and calcium of coagulation.

During muscular contraction the anisotropic substance imbibes from the isotropic; and the presence of a calcium salt is necessary to coagulation. When, as in the case of certain salts, the potential of the crystallizing molecule demands additional atoms of a certain total positive potential in order to crystallize, these may be furnished by molecules of water. When crystallizing or coagulating molecules have relatively larger potentials, as in the case of the molecules of fibrinogen, they require associating molecules of specific dimensions and of specific inductive potentials, so that the aggregate molecular association possesses symmetrical hemispheres with equipotential poles and polar fields. If the globulins, nucleo-proteids and other blood-elements are bases of physiologic units—chromosome and cytoplasmic elements of broken up leucocytes (the

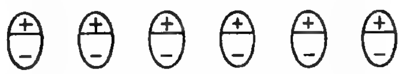


Fig. 81.
Depolarized Molecules of Negative Potential—Unequal Hemispheres.

Fig. 82.
Depolarized Molecules of Positive Potential—Unequal Hemispheres.

Fig. 83.
Polarized Molecules of Positive or Negative Potential—Equal Hemispheres —Coagulation.

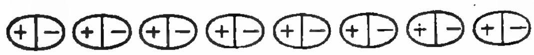


Fig. 84.
Polarized Molecules of Positive or Negative Potential—Equal Hemispheres —Crystallization.

plasmoschisis of Löwit)—it is apparent that they may vary in the quality of their potentials. As chromosome or cytoplasmic molecules they are electro-negative (Fig. 115), becoming neutral on potential exhaustion of the leucocyte, and on its breaking up they become electro-positive. Some of these elements may be neutral, but they are in the most part electropositive. However, more than one organic element seems to take part in the act of coagulation, and these with the calcium salt give an aggregate constituency capable of furnishing symmetrical hemispheres and quantitatively equal polar potentials to the polarizing molecule, whereas salts such as those of potassium with stronger alkaline reactions are disturbing elements and prevent equilibration.

In depolarized molecules the positive and negative atoms may not be divided into hemispheres, and in the figures (81, 82) the hemispheres are intended merely to show the proportion of positivity and negativity in the molecular construction.

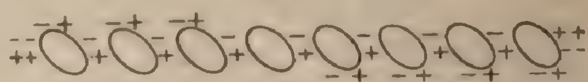


Fig. 85.
Showing Relative Position of Ponderable and Ether Molecules during Polarization.

169. When the surrounding conditions are such that the molecules of polarization are not furnished, polarization will not occur, and crystallization or coagulation is impossible. Excitants to polarization may be a uniform ether-movement in the polarizable mass as in crystallization, blood coagulation or rigor mortis, *i.e.*, on cooling there is an ether-movement towards the surface of the body. Fig. 85 represents a line of mole-

cules, the two ends being at the surface of the coagulating or crystallizing body. The ether is shown as intermolecular, and at the ends is emitted as heat, whilst the ponderable molecules are polarizing. If a uniform movement of the ether is made toward the surface, as in cooling, the ponderable molecules are brought into line and polarized symmetrically (§ 149) as in crystallization. A potential force at a neurone-terminal will polarize neuromeres by attracting unlike and repelling like poles (nerve-stimulation), and the same can be said of the action of electric currents or other stimuli on certain molecules of the blood. The factors of coagulation may be classified:

1. Approximating and bringing into line the polarizing molecules. This is accomplished by an ether-movement as in cooling, or by the electric current.

2. Initiatory stimulation to polarization. This is effected by electric currents, beating with a glass rod, contact with the wall of a diseased blood vessel, etc.; and it involves the same principle as nerve stimulation, or attraction of a molecular pole by the stimulus; and it also involves the same principle as electrification of glass by rubbing it with silk.

3. Association of molecules of polarization. The soluble calcium salts and the "ferment" are no doubt associating molecules.

It is evident that the absence of any of the factors will prohibit blood-coagulation. Hence the coagulating molecule remains in solution in the normal circulating fluid, which is apparently insulated by the tunica intima. On the other hand, when in contact with the wall of a diseased blood vessel its positivities

are attracted and its negativities are repelled—it polarizes and its distal pole excites an adjoining molecule; thus coagulation is effected if the other essentials are present.

CHAPTER XII

The Neurone

170. The term neurone was first used by Waldeyer, and was defined as the histologic unit of the nervous system. It consists of a cell body, with protoplasmic and axis cylinder processes, end arborizations and collaterals. The neurone is a distinct physiologic body, having no break in the continuity of its conducting structure, and it is believed that its branches do not anastomose with those of other nerve conductors. The neurone, however, cannot be termed an ultimate nerve-unit, as a part of it is capable of function; and to the ultimate nerve-unit the term, neuromere, should be applied, as the term, sarcomere, is applied to the muscle-unit. A nuerone is analogous to an electric body, made up of a number of parts, all of them conductors, surrounded by an insulating medium.

171. On looking for an electric body with which to compare a neurone, the author selected the conductor—comb, fork, conducting wire and electrode—of a static machine. This body is excited at the comb, manifestations appear at the electrode, and it is insulated by non-conducting material, and so far resembles the neurone. There is no doubt that the neurone is physiologically insulated; but owing to its special form of conduction it is not necessary that the insulation be electric in character. In fact we know that all soft

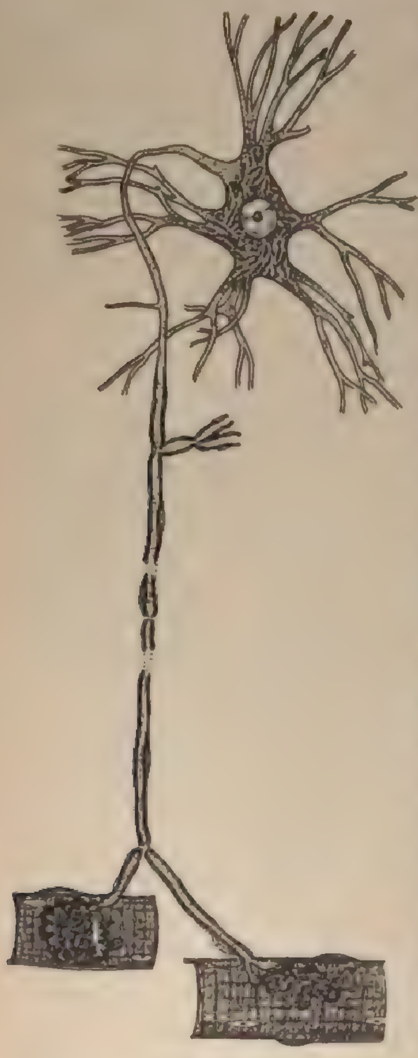


Fig. 86.

Scheme of Lower Motor Neurone. The motor cell body, its protoplasmic processes, its axis-cylinder process, side fibrils, or collaterals and end ramifications, represent parts of a single cell or *neurone*. (*Modified from Barker*.)

tissues of the body are in varying degree electric conductors. All that is necessary is that the enveloping sheath of the neurone-body shall be not endowed with the property of nerve conduction. The myelin sheath is no doubt an electric conductor, and yet it is an insulator of the nerve force. It is the insulator of a magnet rather than that of an electric conductor. (Figs. 86, 87.)

This will be understood when we consider nerve energy and conduction. At the terminals of a neurone there must be, under physiologic, and even more pronounced under certain pathologic conditions, some form of charge which may be identical with, as it acts similarly to, an electric or magnetic charge. There can be no doubt of the identity of nerve and electric force when brought to an ultimate analysis. But a

neurone performs functions which an electric conductor does not; and it manifests phenomena which metallic conductors as the best conductors of electricity are incapable of manifesting.

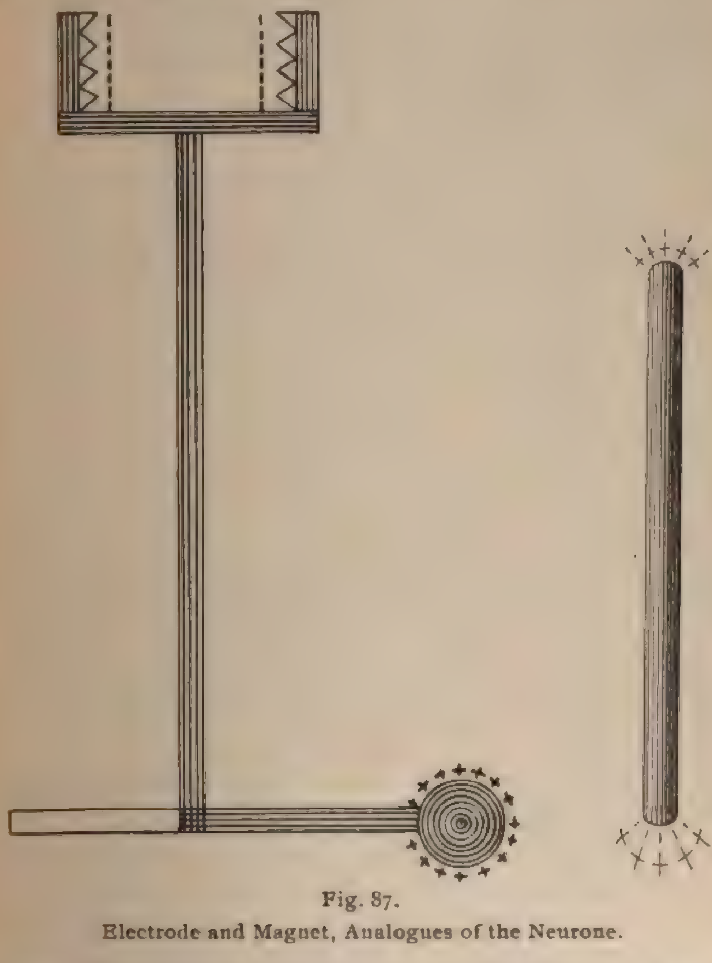


Fig. 87.
Electrode and Magnet, Analogues of the Neurone.

We have then to consider in what respects the force in a neurone differs from the force in an electric conductor; and also the difference between the structure of a neurone and an electric conductor. It is obvious that

in order to produce electric phenomena in the metallic conductor an external force is required proportioned exactly to the work to be done through the conductor, and to the electric potential created in it. With the neurone it is different; a slight touch on a nerve terminal, an indistinct sound, or a faint ray of light is sufficient to excite a nerve terminal, and these forms of excitation in dynamic force are not to be compared with the resulting energy liberated, or work done. Hence we infer that a nerve conductor has a supply of energy or potential not possessed by a simple conductor; and hence we arrive at the conclusion that the fundamental difference between an electric and a nerve conductor lies in the *potential of the molecule*, and that the difference in the potentials of molecules—organic or inorganic—is one of degree and not one of kind. There is, however, this difference between the electric conductor and the neurone: Physiologically the neurone in action has poles similar to a magnet, and the electric conductor has poles at which there is an electric charge (Fig. 124). The neurone has molecules of ponderable matter and molecules of ether differentially polarized at its terminals, whilst the latter additionally has ether split up into its atoms differentially polarized at its terminals. Both can be stimulated inductively.

The hypothesis that nerve force and electric force have a common fundamental basis is strengthened by the fact that chemic analysis establishes the identity of organic and inorganic basic principles. To argue that basic principles are capable of an action in organic substances that they do not possess in inorganic substances, or conversely, is to assume that there are two kinds of chemic action.

The potential of a molecule, as has been previously stated (§ 1, 60, 36), rests on the number and quality of its atoms. The potential of a chemic atom has been defined as the number of free units in the atom's construction, or the number of units extrinsically neutralizable (§ 20, 24). Manifestly the potential of a molecule is the number of free units in its construction. Consequently electric and chemic force meet on the common ground of free ether-units, and these are also the units of nerve force.

172. There are probably many thousands of chemic atoms in each physiologic unit or molecule of a nerve force conductor. The numerical superiority in atoms of the organic molecule to the inorganic of the electric conductor is therefore marked. Organic chemistry favors the conception of the conducting molecule being electro-negative, and of it being composed of atoms having negative potentials combined with those of slight positive potentials. Electro-neural facts support this conception of its character, the correctness of which is essential to an understanding of its means of nutrition, of the forces which govern the osmosis of cells, of the positive quality of initiatory stimuli, and of the necessity of the presence of certain salts to nerve action. Obviously the potential of the nerve conducting molecule is greater than any ordinary electric conducting molecule possessing as the former does the two factors: (1) A great number of atoms giving a potential of concentrativeness (§ 27, 28); and (2) these atoms preponderately inclined in one direction—the negative. The free negativity and the number of atoms in its molecular construction constitute the potential energy stored within the physiologic unit which requires but a slight excitant to be set in action.

173. *Mode of Action.* For the purpose of nerve action a high potential molecule is the first essential. It has been previously stated that the first step in electric conduction is molecular polarization (§ 5). This is equally true of nerve conduction. The molecules must therefore be set in symmetric order and capable of freely moving within their free path or vibratory space. The conducting structure must be homeogeneous, or at least the physiologic units must be capable of being timed as to vibratory pace so as to conform to the rhythm of the specific physiologic excitant (§ 271, § 272). Mode of conduction by the telephone has been discussed, and the method favored is that each molecule receives a vibratory thrill from the preceding one, and conveys the same to the succeeding molecule, having carried the oscillation across its vibratory path (§ 147), and that within the neurone or electric circuit sound-vibration is an alternate acceleration and retardation of molecular vibration or polarization. The trapeziform swing is the only form of vibration whose phases are fully explainable (§ 7). and in nerve tissue, as in electric conductors, ***alternate polarization and depolarization*** occur in each complete molecular vibration (§ 6, § 7, § 269).

174. In Fig. 88, A represents physiologic units or molecules at rest; and B, molecules in tetanized action. In C, the left molecule, representing the peripheral terminal of a nerve conductor, has been excited and is polarized (§ 156), the positive pole is attracted and the negative is repelled by the mass of the nerve in front, which has a large negative molecular potential, the induced fields not being represented (§ 155, § 187). When the first molecule polarizes, its polar induced field excites the second molecule, which polarizes, as shown in

D, the first then depolarizes and assumes its original position, as in E. The polarization of the second molecule is an excitant to the third, hence the wave is propagated. The excitant being still present, the polarization and vibration are repeated. As polarization favors dissociation, on the initiation of the depolarizing act a positive atom, P, and a negative atom, N, separate from the molecule at their respective poles as shown by sec-

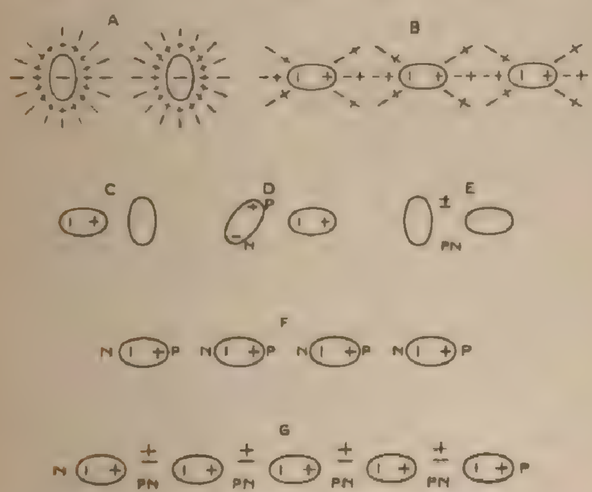


Fig. 88.

Rest and Action of Physiologic units, showing Polarization of Wave and Elimination of Waste.

tion D in the figure. During depolarization, as shown in E, the atoms or ions, P and N, unite, forming carbon dioxide and water. This last act means that a molecule has formed under a lower potential and therefore energy has been set free, as shown by the symbols $\pm$ in section E of the figure. There has been no loss of atoms, only there are two molecules in place of one. The larger or nerve molecule has lost some of its atoms and lost a corresponding amount of potential of con-

centrativeness (§ 27), and of inductive potential, and consequently there is a decreased induced field. The molecular induced fields are shown in A and B (§ 19). The freed energy then is part of the polarized ether in the induced field of the molecule. This energy can follow one of two directions, always seeking the course of least resistance. The ether can immediately depolarize and diffuse as heat, as shown in E, and this no doubt is the physiologic course, but as polarization is the first step in dissociation, it can separate atomically and become an electric charge at neurone-terminals, a course perhaps followed when the nerve is continuously irritated. By F, is represented a neurone polarized, with the induced fields omitted, and in which P and N represent the waste elements dissociated from the unit without further reaction having occurred; G indicates the same neurone with the ions, P, N, united as a nascent molecule with the emission of heat, $\pm$. It will be noted that the nascent molecules are formed from atoms dissociated from adjoining poles of units, leaving the terminal dissociated atoms, N and P, as ions. The terminal ions must then unite by displacement within the structure of the neurone, in a similar manner to the displacement movement in a Daniell cell (§ 111, § 162). This order of neutralization probably occurs in a tetanized neurone (Fig. 124).

In the metallic conductor the polarizing potential or excitant is the atomic ether of the electric current. In a nerve where the molecule is of high potential it is more sensitive to an excitant, and without an electric charge, as in the case of an electric conductor, *the induced polarized field of one molecule is a sufficient excitant to the next in line* (§ 183). The stimulant to polarization of each unit being the induced field of the

positive pole of the preceding unit, it is evident that a positive stimulant to each exists within the structure of the neurone except at the leading off point. Obviously the natural stimulus to the leading off point is one of positive quality, or of neutral character.

The vibration of molecules is rendered possible because they are surrounded by intermolecular ether. The contractile element of the muscle—the anisotropic substance—is surrounded by the more fluid isotropic substance, and there must be similar histologic elements under similar conditions in the nerve conductor. We have only to change the environing conditions of these physiologic units or molecules to see how conduction in a nerve like contraction in a muscle is propagated as a wave; and it is probable that similar waves exist in glands and electric cells.

Although action in both nerve and muscle takes place without the physiologic molecules or units becoming electrically charged, nevertheless continued action, as in tetanus, or a continued irritation from any pathologic condition, will render possible the dissociation of the ether set free, and its polarization by induction at the terminals of neurones (§ 55, § 56) or muscles, as occurs in electric cells; or a similar polarization of nacent molecules may take place, as in electrolytes (§ 42, § 54, Fig. 124). Physiologic demonstration of ether being polarized as electric potentials can be seen in the activities of the electric organs of fish; and electrolytic polarization is demonstrated by the different directions of CO_2 concurrent with the activities of the gastric, hepatic and salivary glands. During physiologic action the poles of a neurone are charged similarly to those of a magnet, as shown in B (Fig. 88), persistent action, however, as in some

pathologic conditions will give them an electric or electrolytic charge. When the neurone depolarizes, all dissociated elements, whether belonging to ponderable molecules or to ether, are neutralized by association, normally within the structure of the neurone.

Conduction in all nerves as regards method is fundamentally the same. They differentiate, however, as to the character of the vibratory impulse conveyed. However, sound is conveyed by the telephone conducting wire apparently just as efficiently as by the auditory nerve, and by substituting a portion of a sensory nerve for a portion of a motor the impulse is still conveyed to the muscle. The differentiation of vibrations therefore must be accomplished at the terminals of the nerves.

The vibratory properties of differentiated nerve tissue whether at the central or peripheral terminals must depend on the quantitative potential of conducting molecules, and on the intensity of their qualitative potential (§20), which is always negative (§ 155). Between the extremes of the quantitative dimensions of molecules, and the extremes of the intensities of their qualitative potential there are an infinite number of combinations affording distinct molecular bodies, with distinctive vibratile characters, fitted to respond to distinctive external vibrations. As certain colors combine and produce white, as certain sounds mutually interfere resulting in silence, and as certain molecules combine and produce chemic neutralization, so there are complementary vibratory periods based on complementary vibratory characters, having the two factors, quantity of matter in, and intensity of potential of the physiologic molecule, the summation of which is a vibratory balance. Consequently we have only to con-

sider the relationship of individual color and sound vibrations to be able to postulate the laws of molecular vibratory differentiation. It is evident, however, that although each molecule has its characteristic gait, that its vibrations may be modified, and that it is capable of intercepting other vibrations. This is demonstrated by the phenomenon of fluorescence.

175. Depolarization, neutralization of ions and a concurrent nutritive process take place in the motor nerves each time the muscle relaxes; in the optic nerve during each period of a wink—thus indicating the necessity of winking—and in the auditory apparatus when we "shut our ears" against noise. In all nerves there are similar periods for rest and recuperation. During sleep there is almost a general depolarization (§ 288).

During tetany of the nerve there exists a fixed neurone-polarization. In this case the molecules or units continue to vibrate, to disintegrate, to split up ether, and consequently the nerve fibril or neurone may become intensely charged at the terminals (§ 294). The vibration is transmitted from one physiologic molecule to another by the vibratory impulse of the polarized induced fields; and the polarized material, whether ether or ponderable matter at the poles of the neurone, also partakes of the vibratory action. The induced field existing at both ends of the neurone—similar to the induced field at the receiver and transmitter ends of the telephone, or to the induced fields of a magnet—being in a condition of oscillation, is thus in a position to affect the terminals of other neurones. Under intense action a molecule in a neurone is in an analogous position to that of a molecule in the part of the secondary coil within the electric field of the primary, that is, each molecule splits up ether (§ 8), with the addi-

tional and inherent property of dissociating ponderable matter, which may be polarized at the terminals of the neurone, as in an electrolyte.

176. *Reflex Action.* The reflex action of nerves is analogous to electric induction (§ 185). Moreover, they are fundamentally identical. The terminals of the neurone are magnetically charged—the excited end negatively and the distal end positively—(§ 182) and the magnetic field influences inductively surrounding polarizable bodies. The charged field therefore is an excitant to the proximate terminals of other neurones (Fig. 122). Reflex nervous action is governed by the same laws as electric induction, but it must be kept in view that the inductively excited neurones are endowed with molecules of high potential, reservoirs of stored energy, readily brought into action by a slight excitant.

The nerve terminals evidently are separated by an indifferent substance, the myelin, which is composed of neurakeratin in which there is a large proportion of sulphur. The specific inductive capacity of sulphur is very great (§ 101), and it is probable that in this element resides the insulatory properties of nerve sheaths. Thus terminal charges may be modified in inductive potential by a change in the relative quantity of sulphur in the myelin sheath (§ 294, § 295). The terminal charge at the distal end of a neurone being separated from proximate terminals of adjoining neurones by neurakeratin, a substance, by virtue of its sulphur, having a high specific inductive capacity, renders terminal conditions similar to that of a Leyden jar, and makes clear how impulses are conveyed from one neurone to another.

Nerve Cell

177. It has been stated that the neurone as defined is a complete neurodynamical or magnetic body, and no doubt this is correct as to continuity of conducting structure. Histologists, however, are not agreed as to continuity of the dendrites with the axone by means of fibrillæ passing through the cell.

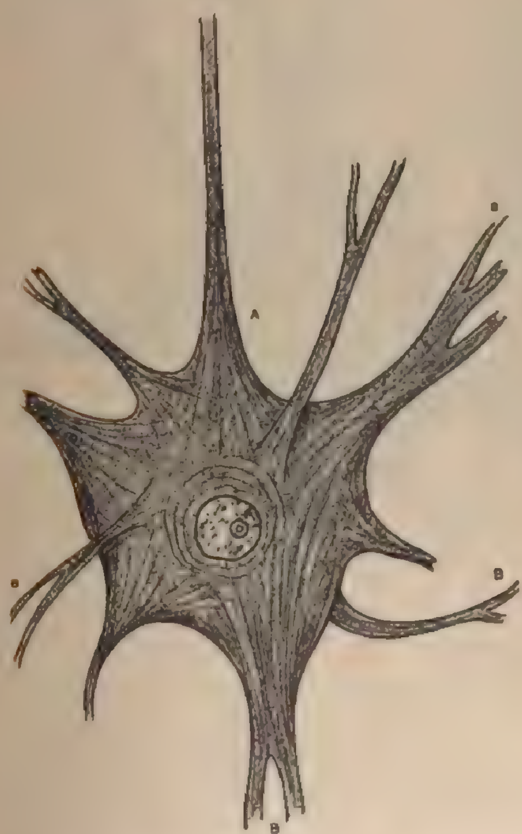


Fig. 89.

Ganglion cell from the electric lobe of the brain of the torpedo as pictured by Max Schultze. A, axis-cylinder process; B, protoplasmic processes.

It is evident that if the fibrils of a dendrite are continuous with certain fibrils of an axone, only the fibrils of the axone directly connected with the dendrite can be influenced by the impulses from the dendrite. In the bipolar cells this plan is sufficient for physiologic

Fig. 90.

Motor nerve cell from ventral horn of gray matter of spinal cord of rabbit. (*After Nissl.*) Of the processes, the one to left of lower represents the axone, showing hillock. All the other processes are dendrites.

purposes. In a multipolar cell where the dendritic processes are numerous, and some of them apparently much larger than the axone, and where they spread over a large surface, showing that they gather impulses from various sources, the plan appears to be entirely insufficient for the purposes of uniform and co-ordinate action. Thus if a fibril in the axone is directly connected with a fibril in one of the dendrites, obviously this precludes the influence of all other dendritic fibrils, except there be anastomosis between them. The histologic differentiation shown to exist between the dendrites and cell on one hand, and the axone on the other, and the existence of the axone-hillock, favor the conception that, in some cells at least, the neurone morphologically has a break at the axone-hillock. If the axone-hillock is composed of granules of high molecular potential, and of intense sensitiveness to molecular polarization, it is conceivable that it is the common starting point of all impulses travelling along the axone-fibrils, and that those fibrils act co-ordinately as a single conductor. In this case the axone-hillock becomes negatively charged by an excitation derived from the protoplasmic mass of the cell, although it is not morphologically continuous with the conducting material of the cell. The presence of the axone-hillock does away with the necessity of fibrils in the cell or in the dendrites being continuous

Fig. 91.
Large Cell from Ammon's Horn of Rabbit. (*After Nissl.*)

with those of the axone. Conducting protoplasm in the dendrites receive impressions at the terminals, which pass through the cell, and thus impress the axone-hillock, the latter being the common medium for the reception of all impressions. The Nissl bodies are made up of granules which are probably storehouses of energy from which the potentials of the conducting molecules are replenished. They may be loaded ships carrying nutrition, sent out from the nucleus to different parts of the cytoplasmic area (§ 239). The basic dyes probably act on these electro-negative granules so as to artificially group them.

The conception has been formulated that the nucleolus is a molecule of great concentrative potential and having an inductive potential of negative quality. Its negative potential attracts positive molecules, such as proteid bodies, hydro-carbons, etc., and the latter are surrounded by negatives, such as the oxygen absorbed during the passage through the lung; electro-positive salts also are present. These form the hyaline substance, and furnish molecules of nutrition, and associating molecules of polarization. The nucleolus, like other physiologic units, is extremely sensitive to electro-positive stimulus. This sensitiveness to positive stimuli is best studied by observing spermatozoa in an alkaline fluid. The nucleolus therefore is continually polarizing and depolarizing. As this is work done, there must be waste—ions dissociated during depolarization (§ 160). The ions uniting as simpler compounds set free energy as heat. The rise of temperature causes a reaction between the positive nutritive elements and the oxygen in their induced fields, and under increased pressure hydrogen carbonate is impressed into the nucleolar molecule as nutrition.

It is probable that under normal action the ions produced at the poles of the unit form CO_2 and H_2O, these substances taking different directions according to the polarity of the structure. Thus in the liver the former goes with the bile and the latter with the blood (§ 260). Obviously they must be separated at the poles of each unit. What probably takes place in the nerve-cell is that some—CO_2—or all of the ions under the increased pressure and temperature unite with positive molecules, such as those of nuclein, and the latter, built up to a negative potential, are repelled by the negative nucleolus, the centrifugal action sending them out of the nuclear area into the cytoplasm. They form the chromosomes of the nucleus, and when outside of the nuclear area become independent units. During the formative stage of the cell the conducting fibril in the cytoplasm may derive its units from the chromosome material. After this is passed the economy of the nerve-cell evidently requires potential-carriers to maintain the equilibrium, and molecules within the nucleus, built up to a negative potential, may travel to and unload at different points of the cytoplasm, thus furnishing nutrition to other units.

The nutrition of the nucleolus is derived from electro-positive molecules, proteids or hydro-carbons, of great concentrative potential carrying within their induced fields a sufficient quantity of oxygen to neutralize part or all of their constituents, and this relationship of the elements essential to combustion no doubt applies to the nutritive molecules of all functionating cells.

The nucleus, and other induced spaces, of physiologic units evidently consist of material of negative potential moving from its center, and other material of positive potential moving toward its center. There must be,

however, in the nucleus of nerve-cells a certain positive element not engaged in the nutritive process which associates the ions, as in the cells of glands, and, as previously stated, this substance may be nuclein. Its molecules resist combustion, having relatively less inductive potential than that of hydro-carbons and other proteids. The products of combustion between the proteids or hydro-carbons and oxygen may be impressed into the nuclein and chromosome molecules without the intervention of the nucleolus. Then the nucleolus would have only the function of an equilibrating or dynamic center, attracting positive and repelling negative potentials. The nuclein molecule may inductively carry oxygen which assists in the combustion of other proteids and of hydro-carbons; the nuclein, resisting combustion at the normal temperature and pressure of the cell, associates products of combustion during metabolism, and, as it passes through the neutral state to a negative potential, releases the oxygen.

The optical properties of the physiologic unit, as manifested by nucleoli and the anisotropic substance of the muscle, are not inconsistent with a molecular character; the highly refracting powers of nucleoli may result from their diameters being much greater than the length of light-waves. The anisotropic properties of the muscle-disc, the light and dark bands, the difference shown by the fiber when resting and when contracting under high power, may be in the line of further investigations which may furnish demonstrable proof that the anisotropic substance is molecular and the isotropic its induced field, the latter having innumerable polarizable bodies which are also molecular in character.

The Nervous System as a Unit

178. The neurone-unit has already been described. If we conceive many thousands of such units of different lengths and with terminal differentiations fitted and adjusted into a harmonious structural whole, each unit capable of acting independently, yet fulfilling an individual part of the physiologic sum, which in its collective character constitutes the ego, such a conception will properly represent the nervous system. Furthermore, as the neurone cannot lay claim to be an ultimate physiologic unit, we can say that arranged in line, delicately and uniformly adjusted and variously superimposed, are molecules of high but of differential potentials, polarizable spherical bodies, the physiologic molecules, which, with their induced fields, constitute neuromeres, and which are capable of conducting vibrations of almost infinite variety, and which at free terminals are capable of differentially intercepting vibratile manifestations. Thus there is a unit nervous system composed of unit-neurones, which in turn are made up of neuromeres the ultimate units of function, which in common with all physiologic units are composed of dominating molecules of high potentials, surrounded by induced fields, and having the common property of polarization.

Neurones may be classified as follow:

1. Peripheral centripetal neurones. Those which have their terminals placed so as to differentiate external vibrations and convey the vibrations selected to the first neural station in the central nervous system.

2. Centripetal central neurones. Neurones within the central nervous system connecting the first cen-

tripetal neural stations with the second, and those connecting the latter with still higher centripetal stations. These inductively pass forward the vibrations received from the peripheral neurones.

3. Projection, commissural, and associated neurones of the telencephalon. These connect the higher centripetal stations with the higher or first centrifugal stations, They cover an area the minute anatomy of which is imperfectly understood. However, in this region inward bound vibrations or sensations are transformed into outward bound vibrations or impulses. Here also vibrations are appreciated and differentiated.

4. Upper centrifugal neurones—upper segment of the centrifugal pathway. These connect the higher centrifugal stations with lower centrifugal stations within the central nervous system. They inductively receive impulses at the upper terminals which at their lower terminals they inductively pass outward to the lower centrifugal neurones.

5. Lower centrifugal neurones—lower segment of the centrifugal pathway. These connect the lower centrifugal stations within the central nervous system with the teledendrions of muscles, glands, mucous, serous and other specialized cells. At the peripheral terminals of these the efferent impulses consummate in muscular, metabolic, secretory, or excretory action.

179. Fig. 92 schematically shows the nervous system divided into representative neurones as classified. The leading off point of a vibration or sensation is shown as electrically negative, the excited molecule turning its positive pole toward a mass of molecules of high negative potential (§ 187, § 188). The peripheral end of the sensory neurone consequently becomes

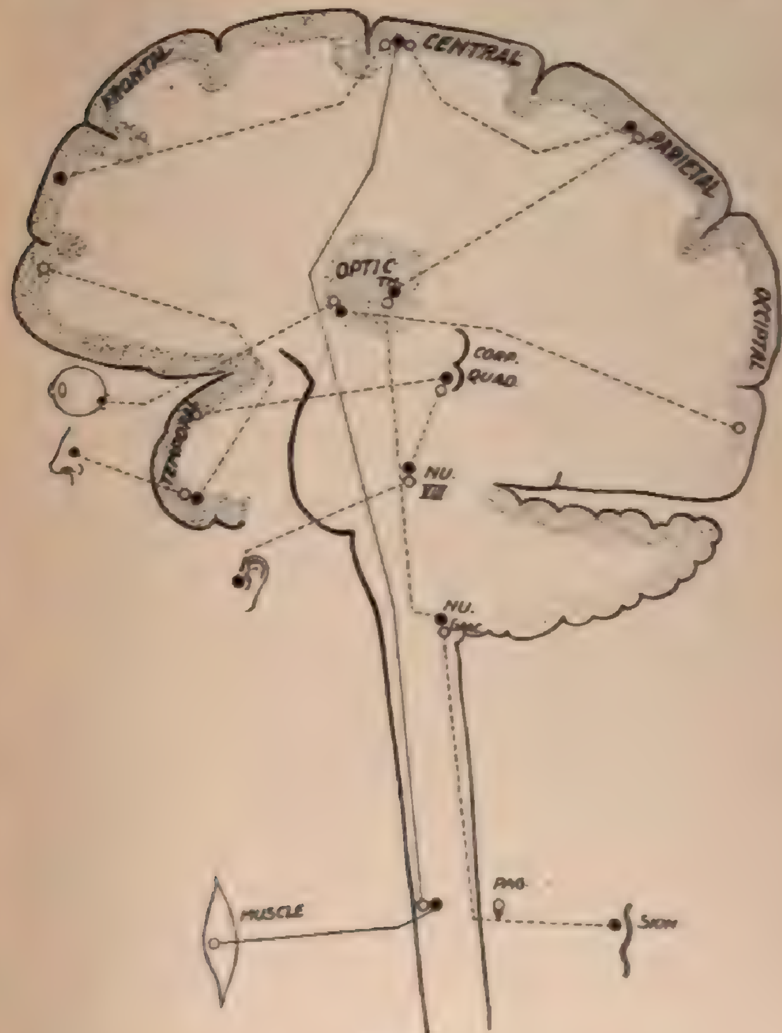


Fig. 92.
Neurones Chained Together ; ●, Negative Terminals, and ○, Positive Terminals. (*After G. P. Wintermute, M. D.*)

electro-negative. Each molecule or physiologic unit in line within the neurone-conductor has positive and negative poles. When excited similar poles point uniformly in one direction, thus producing magnetic or

electric conditions at the terminals of the neurones, each neurone being a complete dynamic body with a positive and negative magnetic pole. Therefore, at the neurone terminals there are induced magnetic or neural fields with an intensity depending on the degree of nerve action within the neurone. The induced field at the forward terminal excites all dendritic terminals within its sphere, thus the nerve movement progresses by induction (§ 65—67, § 185) from one neurone to another.

The fundamental differential character of vibrations, sensations or impulses passing along neurones will be considered in chapter on vibrations (§ 269).

CHAPTER XIII

Physiology of Muscle

180. The anatomical parts of the muscle which concern the electro-physiologist are its peculiar contractile substance and its connective tissue, the latter containing elastic and non-elastic fibers. The microscopic fibers of the voluntary muscles are the primitive fasciculi, which are divided longitudinally into fibrillæ and transversely into discs. The fibrillæ are surrounded by a sheath and the fasciculi by the sarcolemma. The diameter of the fibrillæ is 1/25,000 of an inch, and this must be about the breadth of the discs. Kolliker estimates that there are about 2,000 fibrillæ in a fasciculus. Both fasciculi and fibrillæ show transverse striæ formed of alternating dark and clear bands about 1/25,000 of an inch wide.

181. Muscle substance consists of two materials. The sarcoplasma, which is semi-fluid and isotropic, and which is shown under the microscope as a clear band; and particles of anisotropic material of greater consistency than the plasma, and which the microscope shows as a dark band. The ultimate longitudinal striations or fibrillæ are most evident in the dark bands and are observed only under favorable conditions. Further, during contraction the dark bands representing the anisotropic substance become lighter, and the light bands representing the isotropic substance become

darker. The isotropic substance is divided by a line in its center (Krause's membrane). In the center of the anisotropic substance there is a barely perceptible light line.

When a muscle contracts, not only the muscle as a whole, but each of its fibers and each of its discs are relatively shorter and thicker. Moreover, the volume of the anisotropic substance increases during contraction at the expense of the isotropic material. This is

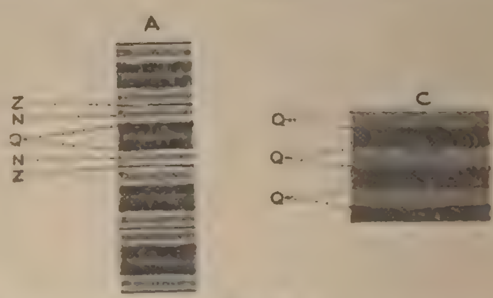


Fig. 93.

Schematic representation of histologic structure of muscle-fiber: A, resting fiber; C, contracting fiber; Z, Krause's membrane dividing light band or isotropic substance; N, dark line passing through isotropic substance; Q, the anisotropic substance with a barely perceptible light line in the center in resting fiber, and shown as the lighter substance in the contraction fiber. (*From the American Textbook of Physiology.*)

explained by Engelmann as an imbibition of the more fluid plasma by the denser anisotropic substance. He gave the reason for the imbibition that heat is liberated by chemic changes the instant that the muscle is excited, and consequently there is an absorption of fluid. Engelmann showed that dead substance, such as catgut, containing anisotropic material, can change its form by imbibition of fluid under the influence of heat, and that it contracts in many respects similarly to a muscle.

There is a tendency on the part of muscle to contract independently of an irritant. The peculiarity is shown by a muscle when cut across, as in a surgical operation, the extremities of the fibers becoming permanently contracted. This is termed *muscular tonicity*.

182. *Character of the Muscle-Unit or Sarcomere.* Like other physiologic units, the muscle-unit is composed of a more solid substance imbedded in a more fluid substance. Like other ponderable molecules, it

Fig. 94.
Muscular Fibers and Sarcolemma.
(*After Wythe.*)

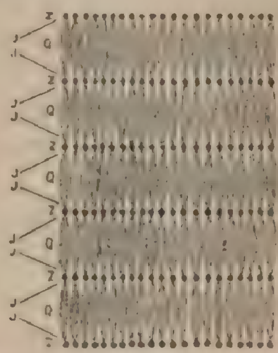


Fig. 95.
Diagram of the structure of the contractile substance. (*Rollet.*) Q, sarcous elements; Z and J, sarcoplasm. The sarcoplasm also lies between the sarcous elements in Q.

is composed of a potential molecular body surrounded by an induced field. The sarcomere is bounded longitudinally by the sarcostyle membrane or sarcolemma, and transversely by Krause's line or membrane in the middle of the sarcoplasm. It thus comprises the anisotropic substance in the center, with sarcoplasm occupying the induced field on either side. The anisotropic substance is the molecular body having great concen-

trative and inductive potential of negative quality. The sarcoplasm or isotropic substance has dimensions corresponding to the inductive force of the anisotropic molecule, and is occupied by material of positive quality, the molecules of which are surrounded by smaller molecules such as oxygen (§ 159, § 243). Intermolecularly placed, filling the interspaces (§ 29), are molecules of smaller dimensions of positive quality consisting of alkaline salts. This arrangement fully accords with the fundamental principle of attraction and repulsion and with the physical properties of matter manifested as solubility, osmosis, etc., and also with the conditions supporting the molecular spacial equilibrium (§ 159). In the relative arrangement of the constituents of the muscle-unit space is economized, force is stored, and physiologic requirements are met. The membrane of Krause is the boundary between the induced fields, and, although it may not be entitled to be designated a membrane, the position is analogous to that of the nuclear membrane (§ 244); and it is constituted of free material outside of inductive influence. Hensen's line is on the equator of the molecule, and when the fiber is stretched it divides into two at this line. This is doubtless owing to decrement or modification of pressure under which at least all negative molecules will divide (§ 144).

Myosin belongs to the globulin class, and probably constitutes the base of the contractile protoplasmic molecule. Myosin according to *Chittenden* and *Cummins* is elementarily composed, on an average, as follows: Carbon 52.82, Hydrogen 7.11, Nitrogen 16.17, Sulphur 1.27, Oxygen 22.03%. The elementary proportions about conform to those of the elements of nuclein, with the substitution of sulphur for phos-

phorus. The molecules of both are positive in quality. Based on the above elementary computation, and considering myosin as the base of the molecule, the physiologic unit of the muscle will have a formula as follows: $-O_nN_nS_nC_nH_n+$. Although phosphorus does not seem to be a component of the base, it may nevertheless be a constituent of the electro-negative group of the muscle-molecule, and the complete formula of the unit may be $-O_nN_nS_nP_nC_nH_n+$ (§ 159, § 160). The introduction of sulphur as a constituent does not modify the fundamental principle of function, neither does it alter the character of its nutritional or waste elements.

All molecules by their immolecular forces assume the spherical form when not distorted by extrinsic force. When the sarcomere is relieved of pressure by the elastic sheath it assumes the form which the intrinsic forces direct. This is shown by the tonicity of the muscle, and is based upon the elasticity of the muscle-molecule, enabling it to recover its spherical form when the force of distortion is removed. Although a form of contraction tonicity rests on a different principle from contractility. Tonicity is a manifestation of elasticity, whilst contractility is fundamentally a polarization of the sarcomere.

The active force of the unit resides in the anisotropic substance and is negative in the quality of its inductive potential. · The induced field is mainly positive. However, the difference of potential quality does not induce chemic reaction. Moreover, when chemic action takes place it is initiated by the potentials of, and occurs between the elements of the induced fields (§ 159); and the nutrition of the muscle-molecule is accomplished by extrinsic pleasure.

Under physiologic conditions, and when the muscle is at rest, the elastic fibers of the sheath *distort* the muscle-molecule and its induced field so that the field does not uniformly surround the molecule. They are comprised within longer and narrower boundaries. Thus the property of elasticity of the sheath is an important factor in the endowment of the muscle with the property of contractility. If the elastic sheath did not lengthen and flatten the muscle-molecule and its induced field there could be no contractility, as without distortion by the elastic fibers the unit would retain the form which its inherent forces direct, and there could be little further shortening of the muscle when stimulated by an excitant to polarization of its molecular units.

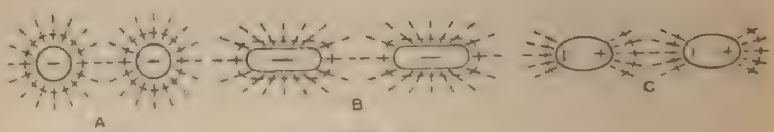


Fig. 96.

Muscular units or sarcomeres: A, free without distortion, as in tonicity; B, distorted by elastic sheath and at rest; C, polarized during contraction.

183. The fact of the elasticity of the sheath distorting the muscular unit accounts for the readiness of the muscle to contract slightly and readily when the sheath is weakened or cut across, as manifested by the property of tonicity. We have mentioned two properties of the muscle-unit, that of being capable of distortion, which takes place when subjected to the elastic force of the sheath; and that of elasticity, which gives it the power to assume the globular form when the distorting force is weakened or withdrawn, and which manifests itself in the tonicity of the muscle. The

most important property of the sarcomere, however, is its power of modifying its form when subjected to an external exciting force. This force may be nervous, electric, thermic or mechanical, and the response is known as the property of contractility.

There is absolutely no means of explaining the property of contractility of muscular tissue, except by assuming that the ultimate sarcous elements or sarcomeres are capable of *molecular polarization*. The high potential and the environment of the anisotropic molecule are favorable to polarization (§ 174, § 185). It has been pointed out that in crystallization the molecules become polarized and the crystallized mass assumes a definite and characteristic form; so, also, in the contraction by polarization of muscle-units, the muscle assumes its distinctive form. When a muscle contracts it becomes round, hard and tense, and this change depends on the condition of the sarcomeres. Each anisotropic molecule is under a condition of *strain*, *is polarized, becomes spherical with equipotential hemispheres* (§ 149) *and with differential poles and differential polar fields.*

The irritant may affect a number of units instantaneously, that is, initiatory units of a number of sarcostyles, consequently simultaneous polarization of sarcostyles takes place. The intense induced field of the polarized unit is an excitant to the adjoining unit, therefore the contraction or polarization is propagated as a wave. The impulse is conveyed from one unit to another by the induced polar field of the first unit stimulating the proximate unit. There is no actual contact between the anisotropic molecules, any more than there is contact between the primary and secondary coils of a faradic battery, and the means of induction

or polarization is through the induced fields in both instances (§ 67, § 29).

184. As molecular polarization favors dissociation, elimination occurs from the construction of the anisotropic molecule, of positive and negative ions, probably oxygen, carbon and hydrogen. These ions are held in the polar grasp of the anisotropic molecule as long as the physiologic unit is polarized. Polarization being effected by a rearrangement of the atoms within the molecule, in a high potentialed molecule, groups of ether-units or chemic atoms are eliminated rather than return to their former placement. The energy represented by the dissociated atoms is equal to the expenditure of energy by the molecule polarizing, and to the amount of energy absorbed by the corresponding nutrition (§ 146, § 147).

When the anisotropic molecule undergoes polarization, and assumes symmetrical hemispheres of specific dimensions, it absorbs material in molecular proportion. This absorption is analogous to water imbibed by crystallizable substances as the water of crystallization. The imbibition from the surrounding plasma is not effected by heat, as suggested by Engelmann, as heat is produced after the depolarizing act. During depolarization the ions unite, probably forming CO_2 and H_2O, hence the heat.

The ether changes that take place are the absorption of ether into the induced fields of ions, and the setting free of molecular ether as heat through the union of the ions as simple compounds.

The shortening and thickening of the muscle is produced by polarization of the anisotropic molecules with equipotential hemispheres, and qualitatively differential and quantitatively equipotential poles and polar induced

fields, thus overcoming the elasticity of the sheath or sarcolemma; and this is rendered possible by high concentrative and inductive potentials of the anisotropic molecule, and its being imbedded in the isotropic substance, from which it is furnished molecules of polarization (§ 146, § 149) and molecules of nutrition.

We have seen in the faradic battery an initiatory force entering an iron core and emerging multiplied by the inherent potential of the iron molecule. The molecule wherein resides contractility has a much larger potential than the iron molecule, so that a slight initiatory force passing into the muscle is similarly multiplied by the inherent potential of the molecule. This is spent in propagating the contraction wave and overcoming the resistance which it meets in its progress.

185. *Relationship of the Anisotropic Molecule to the Isotropic Substance.* Polarization is evidently the important fundamental principle of contractility. The polarization of the ether molecule is rendered possible by ether having no frictional properties, consequently an ether molecule has perfect freedom in the modification of its form (§ 38). The vibration or polarization of an ordinary molecule of ponderable matter is made possible by its being surrounded by intermolecular ether, thus giving the molecule a free field. The environing conditions of the anisotropic or muscle-molecule are equally plain. The anisotropic molecule is imbedded in the semi-fluid isotropic substance, giving the former perfect freedom as regards polarization and modification of its form. The isotropic substance fills up the free vibratory space of the polarizing anisotropic molecule, and occupies a position analogous to intermolecular ether in the latter's relationship to a vibratory ponderable molecule. But the isotropic sub-

stance possesses other functions. It supplies the anisotropic molecule with associating molecules of polarization, an essential to the accomplishment of polarization or contractility, just as the water of crystallization is to the crystallization of certain salts.

What are these molecules of polarization which are necessary to the polarization of the anisotropic molecule, and therefore to contractility? It is probable that they consist of calcium carbonate or sodium chloride, or some other soluble salt. *They are associated and dissociated as molecules*, no chemic change taking place. These associating molecules may be different for voluntary and involuntary muscles; and may even differentiate according to the potential of individual muscle-units.

The transformation of force is as follows: The anisotropic molecules are polarized by an initiatory exciting force and by their inherent potential, the latter being the greater and more important. The act of polarization results in the formation of ions. The anisotropic molecules consequently must have lost in potential, that is, in the number of atoms in their construction. Independently, therefore, of the dissociated molecules of depolarization (§ 160), ions must be given off from the constituencies of the anisotropic molecules. It has been stated that these are probably carbon, hydrogen and oxygen (§ 162, § 163).

Accordingly the function of the isotropic substance is important. It furnishes the associated molecules of polarization to the anisotropic molecule, and also furnishes *molecules to build up* the anisotropic molecule after the latter has lost potential by polarization. The latter is a nutritive process, and is accomplished by combustion of nutritive molecules within the isotropic

substance. Consequently the function of the isotropic substance is three-fold. *It forms the vibratory space of the anisotropic molecule, holds in solution associating molecules of polarization, and is a storehouse of nutrition.*

Generally, the principle of the transmutation of force connected with functional activity is the splitting up of molecules into ions, associating molecules as nutrition and dissociating ions as waste; these ions combining in simpler forms set free energy—ether from the polarized induced field of higher potentials—the freed energy radiating as heat or circulating as electricity; or, under favorable conditions the ions with the energy may be stored in other molecules (§ 208, § 159).

Electric Properties of Muscle

186. Scientific experiments conducted by able investigators, such as du Bois Reymond, Hermann, Mateucci, Bernstein and other physiologists, have furnished elementary facts whereby conclusions may be arrived at as to the character of nerve and muscular action.

It has been shown by du Bois Reymond that there are body currents, which are the resultant of individual currents, differences of potentials existing between various parts of the body, the elbow being positive to the hand, and the chest to the foot. The hand is sometimes positive to the foot and sometimes the reverse (§ 153).

Currents of Rest. Du Bois Reymond demonstrated that a muscular strip under certain conditions and when intercalated in a circuit is the seat of an electromotive force capable of deflecting the galvanometer

needle, and that such deflection is directly proportional to length and thickness—dimensions—of the intercalated muscular tissue. He showed that the muscle-current is coincident with the physiological properties, being dependent upon the maintenance of the normal metabolism; that the current lessens as the processes of retrogression go on, and when rigor mortis is established ceases entirely. He also found that within certain limits the electro-motive force is increased by heat and decreased by cold, according to the degree of influence on the vitality of the muscle.

Du Bois Reymond demonstrated that muscular contraction according to its intensity and duration decreases the muscle-current. This is shown by stimulation of the nerve supply of the muscle by an interrupted current when the muscle is intercalated in a galvanometer circuit.

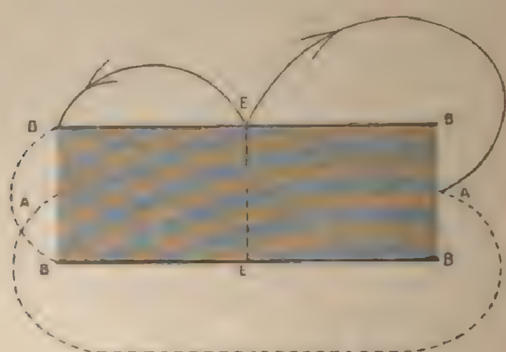


Fig. 97.
Schematic Representation of Currents of Rest.

187. Fig. 97 shows shema representing piece of muscle with normal longitudinal surfaces, B E B, and two artificial cross sections, B A B. The line E E shows position of equator. The arrows show direction of the positive current when the indicated points of different

potential are connected. The broken lines connect points having the same potential and giving no current. If the points marked by similar letters are connected there will be no current; whilst the connection of those marked by dissimilar letters will furnish a current.

By removal of the tendons at the end of a cylindrical muscle a piece, prismatic in form, with a natural longitudinal and two transverse artificial surfaces, is obtained (Fig. 97). If the longitudinal and transverse surfaces are connected in a conducting circuit, in which there is a galvanometer, it will be found that in every instance the positive electricity passes from the muscle, through the longitudinal surface, thence through the circuit. It is found that the greatest electro-motive force exists when one electrode is placed at the middle or equator of the longitudinal surface, and the other at the center of a transverse artificial surface; and that according to the variations from these points the current will be diminished.

Prof. Hermann maintained that in an absolutely uninjured passive muscle currents are not demonstrable, and that the muscle-current manifestations were owing to a difference of potential created by the injured surface of the muscle.

188. Explanations of the phenomena attending currents of rest are as follow: The negativity of the point of excitation of a muscle and the positivity of the other end of the wave are caused by the negative potential of the muscle-unit, the anisotropic molecule having a negative inductive potential which dominates the sarcomere. *The muscle-unit excited turns its positive pole toward the greater part of the muscle mass which has a free negativity* (§ 155). Each muscle-unit has a positive stimulus within the muscle excepting the initiatory

unit. It follows that the natural extrinsic stimulus is also positive.

With an artificial surface and a natural surface united in circuit the point of excitation is always on the injured surface. When a piece of muscle with artificial surfaces is placed within a circuit, a current will be produced in the circuit from the potential of the molecules, providing there is an excitation point, and providing the position of the pole varies in relation to mass-negativity. If, for instance, the centers of two artificial surfaces are connected (Fig. 97, A), the negative mass in front of either pole is equal in dimensions to that in front of the other pole; and at both points the ether in the induced fields of the reacting molecules tends to a negative potential—isoelectric—the positive ether at both points being equally attracted toward the negative mass, consequently there is no current. This is an analogous condition to that of a galvanic cell without a negative (copper) plate, or with two zinc plates, and the reactions in the cell and those within the isotropic field are identical in character. On the other hand, if the muscle-mass varies dimensionally in its relative position to the poles there will be a current, as the difference of mass-attraction will create a difference of potential in the circuit. This current, called the current of rest, is directly proportional to the number of molecules of high potential within the circuit. The current is a manifestation of chemic action taking place *between the nutritive molecules in the isotropic substance and the oxygen in their induced fields*, and does not depend upon the polarization of the disc. The positive nutritive molecules such as the hydro-carbons and proteids and the negative oxygen furnish the essential elements of combustion, and readily react when

resistance to the escape of energy—ether from induced fields—is lessened (§ 43).

When heat is applied to a muscle placed within a circuit the radiating ether-molecules are split up, as in the thermo-electric cell, thus re-enforcing the current of rest (§ 103).

When the elastic pressure of the sheath is maintained and the muscle is excited to action, such action will lower the molecular potential of the nutritive elements, and the subsequent muscle-current of rest will decrease accordingly.

An absolutely uninjured muscle will not furnish currents of rest because there is no excitation point, the discs being protected by an indifferent substance, which also acts as an insulator, thus breaking the circuit.

The muscle current depends on the potentials of the molecular elements in the anisotropic substance, but even after the muscle is removed from the body, metabolic changes between the elements of the muscle-plasma will take place, thus furnishing a current.

189. *Negative Variation Current.* Du Bois Reymond discovered that if the normal longitudinal surface and an injured transverse surface of a muscle were connected with a galvanometer, and the muscle stimulated to tetany, the galvanometer needle will swing back towards zero, where it remains during stimulation. He called this the negative variation. It continues as long as the muscle is tetanized. When the stimulus to the muscle is withdrawn the current of rest manifests itself in the usual direction but lessened in quantity according to the duration of the stimulus.

The so-called negative variation is simply a lessening or absolute negation of the current of rest by a contin-

uous polarization ot the muscle-units by tetanizing the muscle.

During polarization the elements of the induced fields are held fast at the poles of each muscle-unit and are prevented from chemic reaction by being in the possession of a greater force. Consequently the molecules of nutrition which furnish the rest-current, and the waste-elements which furnish the action-current, being within

Fig. 98.

Record of changes in electric potential in a tetanized injured muscle of a frog. The leading off non-polarizable electrodes connected with the capillary electrometer touched the normal longitudinal and injured cut surface of the muscle. The muscle was tetanized by an induction current applied to its nerve, the rate of interruptions being 210 per second. A rise of the curve indicates an electric change of opposite direction to that caused by the injury. The diminution of the current of injury, which was less than in some other experiments, was 0.008 volt. The time record at the bottom of the curve was obtained from a tuning fork making 500 double vibrations per second. (*After Burdon Sanderson.*)

the grasp of the polarizing current-influence—tetanized —cannot furnish potential for another current. During each relaxation of the tetanized condition depolarization takes place. This will free potential for an action-current. However, this current may not be recorded, owing to the mechanical impossibility of the needle following the frequencies of the variations, as in the case of faradic currents; and the ions of waste may be collected at

the terminals of the neurone through the influence of the tetanizing current; or collected at the poles of the tetanizing current.

190. *Action Currents.* The term action currents has been applied by Hermann to currents produced while the muscle is contracting. He divided them into phasic and tetanic.

When the muscle is excited so as to produce a single contraction the point of excitation becomes negative, the opposite point of the wave positive, and the direction of the current produced accords with the character of these electrifications. This is the first phase. Immediately following this is a current in the opposite direction, which is the second phase. Therefore the current is diphasic. When the muscle is in a tetanic state the waves follow each other so closely that a single current is produced, the direction of which coincides with the first of the phasic currents. During the production of the tetanized current the point of excitation is negative to any other point in the muscle, as shown when the points are connected in a galvanometer circuit.

When the muscle is excited through the nerve, and the tendinous ends are connected with a galvanometer, the action is shown to be diphasic. The first excitation-wave, according to Hermann, proceeding from the nerve or middle of the muscle, towards the ends—atterminal—and the second reversely—abterminal. The latter is always the weaker, and absent when there is an artificial transverse section.

Du Bois Reymond and Hermann succeeded in demonstrating that the voluntary contractions of muscle in the living were attended by electrical changes, similar

to those in a muscle removed from the body and described as action currents.

Mayer demonstrated that when the tendons of the gastrocnemius muscle were connected with a galvanometer, and a single stimulus applied through the nerve, diphasic currents took place, and that the excitation wave proceeded from the end plate of the nerve. During the first phase the lower end of the muscle was positive, and during the second phase the upper end became positive.

191. When a muscle contracts the anisotropic molecules are polarized and ions are eliminated at the poles. On depolarization the ions form simple compounds and ether is set free. When the muscle is enclosed in a circuit the ether escapes as a current of electricity, this path offering less resistance than that of heat radiation. The leading off point, which is negative (§ 188), gives direction to the wave of contraction and to the current constituting the first phase. The second phase of a current from a single contraction is concurrent with depolarization of the discs, the current being directed by the negativity of the muscle-mass, and not, as in the first phase, by a polarized mass. The phases are analogous to the closed and open periods of induced currents. The first phase is a dissociation of the ether within the intermolecular spaces of the circuit caused by the polarization of the muscle—the closed period of induction. The second phase is depolarization or neutralization of the polarized ether of the first phase —open period of induction (§ 81)—reinforced by ether set free by union of ions of waste. In tetany the energies pertaining to the muscle are held fast by the tetanizing current, the intermolecular ether of the circuit however is disturbed.

When a muscle is excited by nerve action the point of excitation becomes negative because the end plate is positive, and because the muscle-mass is electro-negative, as before explained (§ 188).

Hermann's experiment showing that the first phase of the wave proceeds from the nerve-plate towards the ends—atterminal—and Mayer's experiment that one end of the muscle is negative and the other positive, show that the point of excitation under those conditions was negative as to the wave toward one end, probably toward the larger portion of the muscle, and positive as to the wave proceeding to the other end of the muscle, the muscle-units polarizing in uniform direction throughout its mass. This is the only way in which a current could flow in the circuit. The larger mass of the muscle directs the current and causes its end to be positive, during the first phase; or, if the direction of the positive part of the current is followed, it proceeds from the point of excitation towards the end of the muscle having the greater mass, throughout the circuit to the other end, and from this back to the point of excitation. The negative current starting from the same point proceeds in the opposite direction.

The electric properties of muscles may be stated thus:

1. Rest-current, derived from chemic reactions between nutritional molecules and the oxygen in their induced fields, both being elements of the isotropic substance.

2. Action-currents, from energy set free by union of ions of waste dissociated from anisotropic molecules; or from disturbance of intermolecular ether

within circuit, by polarization of the muscle as part of the circuit.

3. Negative variation, caused by the potentials of the muscle-unit being taken possession of by extrinsic force; or by a polarized mass giving differential direction to a current from that given by a resting negative mass.

Electric Properties of Nerves

192. The similarity between the electric properties of nerves and those of muscles is so striking, not only in experimental facts, but in governing principles, as to be suggestive of a common histological basis for the two structures.

Rest Currents. To du Bois Reymond belongs the credit of discovering electric currents in nerves. When a section of a nerve is made, with a natural longitudinal surface and two artificial transverse surfaces, it will show electric properties, under the same conditions, similar to those of the muscle-cylinder. The electro-neural and the electro-muscular phenomena, and the laws governing the phenomena are similar or identical throughout, as far as the smaller transverse surface of the nerve will allow experimental research. The same law governing the polarity of the current applies to nerve currents as to muscle currents—the excited point becomes negative, the positive molecular pole being attracted towards the negative nerve-mass.

After the artificial surface of the nerve cylinder has lost its irritability a new section will renew the electromotive force. Excessive heat or cold, induction shocks

and other influences, by hastening chemic changes, diminish the nerve-current.

In the muscle rigor mortis stops the current entirely; in the nerve, this physiologic change being absent, the current decreases gradually. The nerve fibers of the brain lose their potential first, then the fibers in the spinal cord, and lastly the nerve trunks. The potential disappears in the direction from the center to the periphery. Hermann denied that currents of rest existed in a nerve which was entirely uninjured, regarding all parts as isoelectric.

193. *Negative Variation.* When the transverse and longitudinal surfaces of a section of nerve trunk are connected in a galvanometer circuit, and tetanic stimulation made, the needle will at once swing back to zero, manifesting the negative variation, as in the muscle. Chemic, mechanic, or thermic stimulus of the nerve within the circuit will also cause a negative variation. Physiologic sensory nerve-impulses have been found to produce negative variation. Light falling on the retina of a frog's eye was found to cause negative variation in the optic nerve.

An interesting experiment made by du Bois Reymond showed that strychnin poisoning will produce a negative variation. He divided the sciatic nerve of a frog at the knee, and freed it from its connections up to the spinal cord, and then connected the transverse with the longitudinal surface in circuit. Strychnin was then administered to the animal. During the spasms the galvanometer showed the negative variation. This experiment demonstrated that physiologic stimulation of spinal centers produces the variation.

Bernstein showed that negative variation is composed of a large number of single variations in rapid

succession—the current being propagated in the form of a wave, estimated at eighteen millimeters in length, and of a duration of 0.0007 of a second.

194. *Action Currents.* The fundamental facts of action currents in nerves are similar to those in muscles. The stimulated point of a normal nerve becomes negative, and the wave passes along the nerve trunk in both directions. The change is diphasic, as in a muscle. Various chemicals, such as salt, glycerine, or mechanical excitation will act as irritants, but electric currents most readily call forth responses. Macdonald and Reed observed currents of action in the phrenic nerve corresponding in time to respiratory movements. When a nerve is excited in the middle the activity spreads in both directions, causing contraction of a muscle at one end, and negative variation at the other, as observed in a galvanometer.

After Currents. The passage of the galvanic current through a nerve produces a polarization which furnishes a potential capable of giving an after or polarized current when the galvanic current is withdrawn. If a galvanometer is within the circuit of the polarized current, the extent and direction of the after current is subject to galvanometric observation. When the galvanic or electrotonic current is strong and of short duration, the after current has the same direction as the galvanic; on the other hand, when the polarizing current is weak and of long duration, the after current takes the opposite direction.

Extra polar regions also develop after currents. The after current in the anodal region is at first in the same but afterwards in the opposite direction to the anelectrotonic current; whilst the after current from the cathodal

area is always in the direction of the catelectrotonic current.

195. Molecules of very high potential are ever ready to reconstruct under a lower potential. The sarcomere and neuromere contain all the essential elements for such reconstruction (§ 158). It must, however, be kept in view that on undergoing analytic reactions there is a resistance to be overcome. It is true that the same number of atoms exist in the reconstructed molecules as there were previously in the molecule of high potential, but by reconstruction they have partly neutralized their potentials, and their induced fields have been circumscribed (§ 41, § 42), with the evolution of energy. Under reconstruction, if heat is emitted its radiations encounter resistance; if the energy becomes an electric current there is still a resistance. It is this resistance that holds molecules of high potential in balance, and assists them in maintaining their potency. The fact of the chemic action only taking place in certain batteries when in closed circuit will illustrate this idea.

When there is no injury to nerve structure, although placed in circuit there is too much resistance for an electric current, as an indifferent substance is intercalated in circuit; and there is no exciting point to assist in the molecular polarization. When the electrodes are placed on two injured transverse surfaces of a nerve, the mass-negativity in front of each electrode being equal, there is no polarization, and therefore no current. In this case the negative poles of the molecules of the nerve in contact with both electrodes tend to turn respectively towards their proximate electrode, a condition incompatible with a current. The ether in the induced fields of the molecules from which

the energy is set free is attracted isoelectrically, and the chemic reaction is thus resisted. Both excited points tend to a negativity, and the positivities are equally attracted towards the negative mass.

When a nerve is tetanized the ions of waste, and the molecules which furnish them and the nutritional molecules and the oxygen in their induced fields, are held in the grasp of the polarizing current through its initiatory stimulus, and the molecules vibrate in response to the excitation. Consequently, as the forces which supply a rest current are under the influence of the polarizing current, negation of the rest current

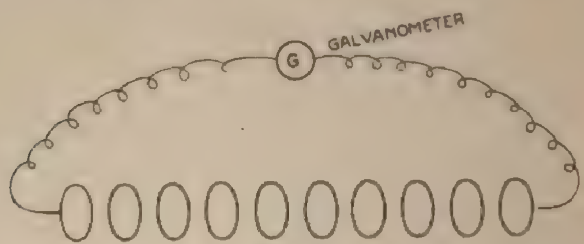


Fig. 99.

Molecules of high potential within a circuit. They are in equilibrium and furnish no current. The induced fields of the molecules are not represented, but they contain all the elements of combustion.

takes place. The combined forces, those of the polarizing current and those set free from the muscle-units, are transformed into heat, polarized at the poles of the polarizing current, or at the polar terminals of the neurone; or they furnish a current in the opposite direction to a rest current (§ 191).

In Fig. 99, there are represented molecules of high potential in circuit, many thousands of atoms in the molecule and these having large inductive negativity. In this position there is no current, as the mass-negativity attracts equally the positive pole of each excited

molecule at the electrodes; nor under such conditions can the nutrient elements of the induced fields react, as the positive element of the ether to be set free by such reaction is equally attracted to the negative-mass at both poles. The conditions are isoelectric.

In Fig. 100, there is represented a natural longitudinal and two artificial transverse surfaces. The electrode at the end of the line of molecules is an excitant. The excited molecule has a mass of negativity in front of it, therefore it turns its negative pole toward the electrode. This constitutes a difference of potential between the electrodes, and a current follows from

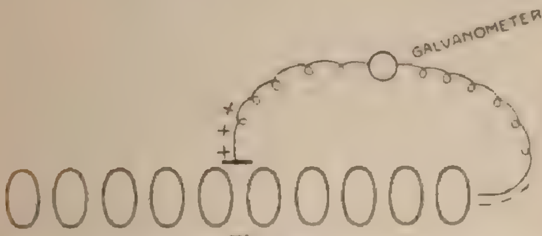


Fig. 100.

Molecules of High Potential, in Position to Furnish a Current.

energy set free by a reaction between the nutrient elements and oxygen in their induced fields, the ether being split up and it elements seeking differential poles.

In Fig. 101, tetanized molecules are represented. They are in fixed polarization. Molecules, and their induced fields, ions, and ether are under the influence of an exciting current and are incapable of giving a rest current. The greater force takes possession of all smaller potentials. When there is sufficient polarized potential to overcome resistance it unites at each molecule and radiates as heat, accumulates as ions at the respective poles of the polarizing current, or furnishes an action-current. This explains negative variation.

When a single shock is given the molecules they polarize, and on depolarization an action-current is manifested in the galvanometric circuit. The plus and minus signs represent positive and negative poles of the units; and P, and N, ions, or chemic potentials dissociated as waste. The ether is polarized in the induced fields of the potentials of the ions. Part of this ether is set free when the ions unite, and radiates as heat, or forms an action-current. Action currents are

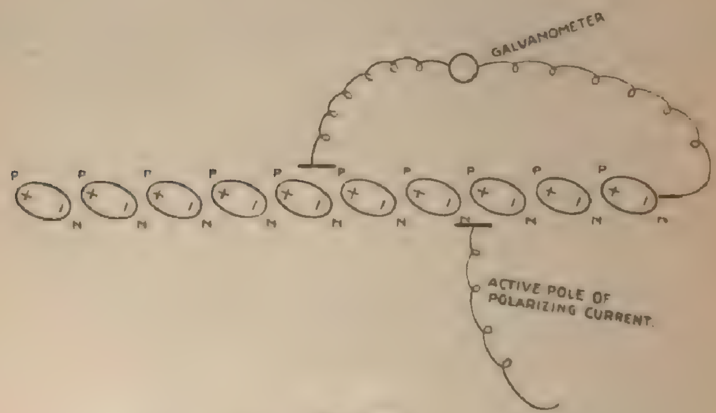


Fig. 101.
Tetanized Molecules with No Rest-currents, showing Negative Variation.

directed by a polarized mass and by the polarizing current; as the currents of rest are directed by a resting negative mass, it is obvious that the direction will be different from that of action-currents, and on this differentiation rests negative variation. The electric propties of nerves may be tabulated in a similar manner to those of muscles (§ 191), only polarization of a nerve is not such a pronounced disturbance of the intermolecular ether of a circuit.

CHAPTER XIV

IRRITABILITY AND CONDUCTIVITY

196. Accompanying the electrotonic state there is an alteration in the irritability and conductivity of the nerve whereby the resulting sensation or muscular contraction is increased or diminished, according to the strength and direction of the galvanic current.

Pfluger formulated the following law: "If any portion of a nerve be traversed by a descending or ascending constant current the excitability of the intrapolar, as well as the extrapolar, regions undergo a change, which upon investigation is found to be *decreased in the neighborhood of the anode and increased in the neighborhood of the cathode.*"

Diminished excitability — *anelectrotonus* — and increased excitability—catelectrotonus—extend on both sides of their respective poles for some distance, but are most marked in the vicinity of the poles in the intra and extrapolar portions of the nerve. The degree of modification of normal irritability and length of nerve affected depends on the strength of the galvanic current and physiological state of the nerve.

197. *Action of Electric Currents on Muscle.* When the galvanic current is sent through a muscle there is a single short contraction at the closing of the circuit, and also at the opening of the circuit. If a strong current be used there may be a prolonged contraction,

which gradually decreases, although it may last as long as the circuit is closed; when the current is broken prolonged contraction may follow, gradually passing away. The closing contractions originate at and may be limited to the region of the cathode; and the opening contractions originate at and may be limited to the region of the anode.

When a weak constant current is used no contraction is manifested, notwithstanding the current modifies the condition of the muscle. In the region of the cathode there is a state of latent excitation, with an increased irritability of the muscle; after withdrawal of the polarizing current, this irritability is decreased, being less than before applying the current. At the anodal region during the application of the current the irritability of the muscle is decreased; but after withdrawal of the current it is increased to a degree above normal.

198. In the case of unstriated muscle the closing of the anode never causes a contraction, and if the part of the muscle under the anode is in a state of tonic contraction it immediately relaxes. The inhibitory influence of the anodal effect on muscle is seen in a remarkable degree when this pole is applied to the heart. If the positive pole is placed on the ventricle of the heart of a frog, the cathode being indifferently placed, relaxation is seen in the region of the anode with each systole of the ventricle. When the anode is placed on an ordinary striated muscle a similar inhibitory influence is shown, if tonic contraction is present.

The amount of irritability developed in a motor nerve by an exciting current is estimated by the degree of contraction of the muscle. In testing the effect of the galvanic current on nerve or muscle it is better to use a small active electrode and a large indifferent one.

The contraction is produced during a modification of the current; only very strong galvanic currents will otherwise effect a contraction.

199. There is in using the anode as the active pole an *anodal make* or *closing* and an *anodal break* or *opening*, and the same with the cathode as the active pole. These make four distinct modifications of the current. It is found that with the same current and under like conditions each of these modifications will produce a different strength of contraction of the muscle excited; or that to produce the same strength of contraction under exactly the same conditions it requires a different amperage for each modification. It is found that the weakest current to produce a contraction is when the cathode is the active pole, and the circuit is closing. The next is the closing of anode. This is followed by the opening of the anode. Lastly comes the opening of the cathode.

200. The following table shows the comparative value of the modifications in contracting muscle:

Weak Current.	*Medium Current.*	*Strong Current.*
K. C. C.	K. C. C.	K. C. C.
	A. C. C.	A. C. C.
	A. O. C.	A. O. C.
		K. O. C.

The poles, closing or opening, and contraction are designated by letters, thus: K. C. C. reads "Kathode closing contraction." It has been shown that closing contraction originates at the cathode, and the opening contraction originates at the anode. *Breaking induction shocks are more stimulating than making, the reverse being true of the constant current.* The break of an induction current is a depolarizing current and

meets no resistance (§ 81). The galvanic current having larger amperage has a more intense effect in closing, whilst its break is only equal to that of the opening induction current.

The table is of value in illustrating the electrical reactions obtained from healthy nerve and muscle. For instance, on applying the cathode to the ulnar nerve at the motor point near the elbow, the anode being placed on some indifferent part of the body, it has been found that contraction of the muscles innervated by it occurred with a current of two milliamperes on closing the circuit; a current of three milliamperes was required to contract when the anode was applied as the active pole, and the circuit closed; from three to four milliamperes to produce an effect when with the anode the circuit was opened; while it required eight milliamperes to contract the muscle when the circuit was opened with the cathode applied to the nerve.

200. *Theory of Anelectrotonus and Catelectrotonus.* An explanation of anelectrotonus and catelectrotonus has been given as resulting from the accumulation of acids at the positive, and alkalies at the negative poles by the electrolytic action of the current. In support of this theory is the physiologic fact that acids when applied to nerve tissue reduce the irritability of a nerve and alkalies increase the same. The theory is unsatisfactory, as it does not explain the differential polar phenomena throughout.

The explanation of the peculiarities of different degrees of muscular contraction, under the four modifications of the current, is extremely interesting and extremely simple.

In Fig. 102, there are represented two lines of muscle-units, A and B, which may be considered as belonging

to different muscles, each having an electric pole applied to its surface; or one pole may be considered as active and the other as indifferent as regards any one muscle. The molecule of the contractile substance is electro-negative when at rest, and becomes hemispherically equipotential when in action (§ 155). At the cathode the negative current will repel the negative part of the unit and attract the positive (Fig. 102, D, C),

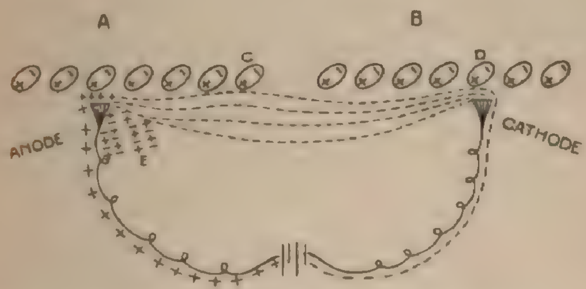


Fig. 102.

Differentiated polar stimulation: A, muscle-units with anode as proximate pole; B, muscle-units with cathode as proximate pole; C, muscle-unit stimulated by diffused current from cathode, after passing through body; D, muscle-unit stimulated by a concentrated current at cathode; E, the symbols ± show neutralization of positive and negative ether from the polarizing current at anode. The units are represented in the act of polarization, which is propagated as a wave from the stimulated point. The poles may be considered as on the cutaneous surface; whilst the interpolar current and the neutralized ether-units are within the body.

and will then carry the positive part along with it towards polarization, thus causing the point excited to be negative. In this the negative current is assisted by the potentials of the negative mass of the muscle in front, which also attracts the positive part of the excited molecules (§ 188). The negativity of the muscle-mass and the negative current mutually supporting, it follows that there is a complete polarization of the

molecules or *physiologic* units and consequently an intense contraction.

At the anode the positive potential attracts the negative part of the molecule, and naturally tends to carry it toward polarization, but this is resisted by the negative interpolar muscle-mass, owing to this resistance the positive current hesitates, and the muscle-element, and muscle-mass are polarized by the current from the negative pole. At the anode polarization in this case is incomplete, and the contraction weak, as it is resisted by the positive current at the electrode (Fig. 102, A), and the stimulus is initiated by a diffuse negative.

It has been shown (§ 46) that the differential potentials of currents favor a relatively rapid negative and a relatively slow positive movement. It is apparent that with common media and consequently similar resistances muscular contraction will be effected by the negative current, and that in the majority of cases the negative is the active pole independently of its position. If the cathode is placed contiguously to the muscle the latter receives the full force of the current on closing, before it is diffused. If the cathode is placed indifferently the current is diffused through the body and only part of it passes through the muscle.

As in the vacuum tube, the currents passing through a muscle meet and neutralize at the anode, and the negative potential passes through the body as the cathode rays pass through the tube, although the method of conduction is different. On opening the circuit different conditions prevail. The position of the break in the circuit must be a factor of importance. It can be readily demonstrated that when a body charged inductively is divided and removed from the electric influence, that the parts are differentially charged; and

in some instances a charge may be left on tissues intercalated in a galvanic circuit when the latter is broken. Bearing in mind that the currents neutralize at the anode, it is apparent that anodal opening by removing the anode from the surface, leaves the tissues negatively charged. Thus the muscle is stimulated by a reverse negative current neutralizing within the galvanic cell. On the other hand, on cathodal opening, by removing the cathode from the surface, the tissues are not charged and the contraction is produced by depolarization accompanied with the neutralization of ions.

It would appear that the factors in the production of differential degrees of muscular contraction by currents are:

1. Concentration of the negative current on entering the muscle, the contraction wave proceeding from the cathode—cathodal closing.

2. Diffusion of the negative current on entering the muscle, the contraction wave proceeding from cathode—anodal closing.

3. Reverse negative current, reinforced by energy set free by neutralization of ions, stimulating the muscle, the muscular wave proceeding from the anode—anodal opening by removal of positive electrode.

4. Energy set free by neutralization of ions accompanying a general depolarization in the tissues, the contraction wave proceeding from the anode—cathodal opening by removal of negative electrode.

The rule prevails that static potentials produce converse results to those of kinetic potentials. Thus chemic positive potentials, positive static charges, and negative current potentials are stimulant; whilst chemic negative potentials, negative static charges, and posi-

tive current potentials are sedative to the function of physiologic units.

When the galvanic current establishes a path the current is carried by molecular vibration without disturbing the muscular discs, except when very large currents are used. The equilibrium of the muscular elements is not disturbed and there is no contraction when there is no modification of the current. The current-vibration passes through the isotropic substance, the induced field of the anisotropic molecule, and the vibratory action of the former resists the polarization of the latter. A molecule cannot polarize with its induced field in possession of another and greater force. On the other hand, a muscle during contraction will hardly be an electric conductor, as two forces cannot occupy the same field. The contraction is produced by the current striking the muscle, not by passing through it, although the initiatory disc is probably electrically charged, the contraction wave being propagated as if initiated by other stimuli.

The increased excitability of a muscle under the influence of a weak cathodal application is explainable on the basis of the conception of a re-enforcement of normal polarization by the cathodal application; and the decreased excitability on the withdrawal of the current as a result of electrolysis of the tissues during the application. At the anode the current opposes normal polarization during the application, hence a lessened excitability; and when the current is broken the anions (oxygen) and cations (hydrogen and carbon) unite at the anode, because the cations are the lighter atoms. Thus the energy, as heat, set free at the anode increases the irritability of the muscle as it does when

heat is applied externally. This energy also excites the muscle on breaking the circuit.

201. *Action of Galvanic Current on Nerve.* On applying a galvanic current to a part of a nerve there is a modification of the nerve current—the current produced by a part of a nerve in separate galvanometric circuit (§ 192). There is also a modification of the irritability of the nerve—its physiologic response to stimuli. The modification of the properties of the nerve has been called *electrotonus*.

In this respect the galvanic current has been termed the *polarizing current*, and the modified nerve current has been named the *electrotonic current*. Experiments indicate that when the galvanic current is flowing through a limited portion of a nerve, all other portions exhibit the presence of electrotonic currents, which are related to the galvanic current.

It has been found that the polarizing current produces a different modification of the nerve current, and of nerve irritability, at the galvanic anode from that produced at the cathode. The modification at the anode is called *anelectrotonus*, and that at the cathode *catelectrotonus*.

Electrotonic Currents. The nerve current of anelectrotonus slowly reaches its maximum and slowly declines; on the other hand, catelectrotonic current rises quickly and quickly declines. The anelectrotonic current has a direction toward the polarized region, and the catelectrotonic current is directed from the polarized region. Both follow immediately the closing of the galvanic circuit and depart on opening.

Electrotonic currents increase in strength with the polarizing current until they reach a degree that attacks the integrity of the nerve-structure. They are

strongest in the region of the electrodes of the constant current, decreasing outwards from the polarized region, the distance affected depending upon the strength of galvanic current and the physical condition of the nerve. The anelectrotonic current is greater than the catelectrotonic current, and both are increased by embracing within the interpolar space a greater part of the nerve, with a corresponding increase of the polarizing current.

Electrotonic currents depend on a modification of nerve structure by the polarizing current, and are not merely a diversion of the polarizing current into the galvanometric circuit. This has been proved by substituting wet thread and other material for nerve tissue.

After the galvanic current is withdrawn the galvanometer will show an *after current*, the direction of which varies according to the strength and duration of the previous galvanic current. When the galvanic current is strong, and short in duration, the after current has the same direction as the polarizing current. When the polarizing current is long in duration, and weak in strength, the after current is the reverse in direction to the polarizing current. After currents are also present in extra polar regions, a remarkable feature of which is that on opening the galvanic circuit, the anodic after current at first accords in direction to that of the anelectrotonic current, followed by a change in the opposite direction; on the other hand, an after current from the cathodic region is always directed in the same way as the catelectrotonic current.

202. In Fig. 103 a line of physiologic molecules or units is represented, stimulated by a galvanic or polarizing current. The negative current is shown as

charging, at the cathode, an approximate nerve-molecule or neuromere and at the same time attracting its positive constituents. As the negative charge travels towards the anode the unit polarizes with a negative leading off point. It thus acts with normal polarization of the nerve. It is clear that if the negative

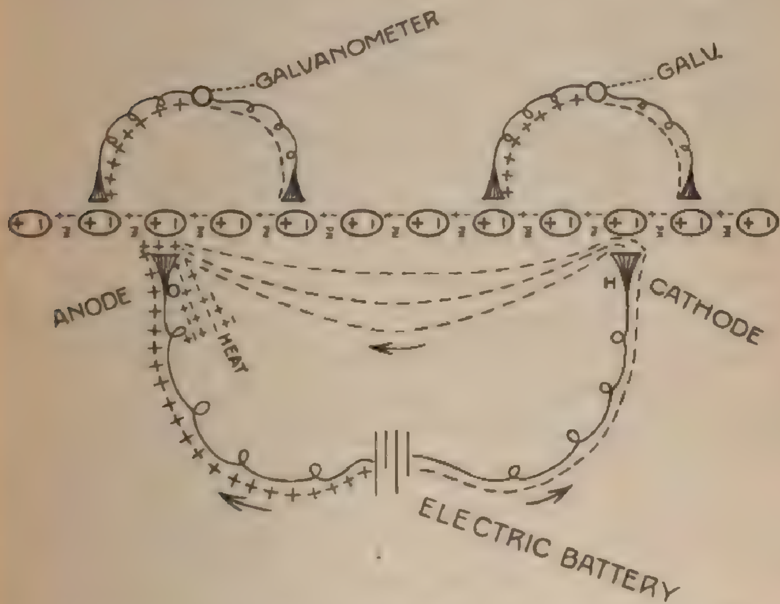


Fig. 103.

Illustrating galvanic currents passing through organic structures and initiating a neural wave, with electrotonic and after currents. The anode and cathode are placed on the surface, but the interpolar part of the figure illustrates action taking place within the tissues.

potential were static it would attract and hold the positive hemisphere of the unit, and thus act against normal polarization. When the initiatory unit is polarized the polarization-wave proceeds independently of the current, the latter taking a path through adjoining structures, as in muscular contraction. Further,

it is clear that the polarization or conduction-wave is initiated by a direct charge, and not by induction, as a negative current acting inductively gives a positive leading off point, as shown in Fig. 29. Moreover, in Lott's experiment (§ 237) the cells are movable and are attracted inductively to the anode, and when positively charged move with the current towards the cathode. The fundamental difference between the movements of spermatozoa and muscular or neural waves evidently rests on the motility of the spermatozoa and the fixity of the units of muscular or nervous tissue.

The polarizing current neutralizes in the neighborhood of the anode as shown by the symbols [illegible] at that pole; consequently that part of the circuit is where heat is mostly developed. The heat—molecular ether—may be transformed into part of the electrotonic current (§ 103). The ions resulting from galvanic action are shown as H, and O, at their respective poles, and are produced from tissues adjoining the line of molecules shown in the figure. The ions, with the heat produced, represent the work done by, and are commensurate in potential with the energy of the galvanic current (§ 55). But just as a slight irritant, as a ray of light, will set up disintegration in a nerve incomparably greater than the exciting force, so the galvanic current, acting as an excitant to nerve tissue, must produce dissociation beyond its measure of force (§ 172). The extra ions produced represent the inherent force of molecules of high potential, and are designated by the letters P, and N. The union of the ions sets free energy designated by $\pm$ between the units which, under proper conditions, constitutes action or electrotonic currents. They do not collect at the poles of the galvanic current, because that current has its force fully occupied

by its own electrolytic work. They unite during the flow of the polarizing current at the moment of depolarization of individual molecules, and the energy—ether—eliminated circulates in the galvanometric circuit, because that course offers less resistance than that encountered by the energy radiating as heat.

The course of the electrotonic current is directed by the inducing influence of the galvanic current, and is therefore in the opposite direction to the polarizing current. It has been pointed out that the polarizing positive current is opposed to the normal polarization of an organic unit, and that the negative polarizing current assists normal polarization. This accounts for the anelectrotonic current reaching its maximum slowly and slowly declining in comparison with the catelectrotonic current. The anelectrotonic current is greater than the catelectrotonic current because part of the polarizing current is evolved as heat (Fig. 103) at the anode. This heat is converted into an anelectrotonic current, that being the course of least resistance to its radiation (§ 103). Extrapolar electrotonic currents demonstrate that the whole nerve is excited to action, as it is by other excitants. When the polarizing current is withdrawn, the ions, H and O (Fig. 103), unite and energy is set free which again excites the whole nerve, and inter and extrapolar after currents result.

The direction of after currents is in the opposite direction to the exciting current, just as a polarized current is opposite to the galvanic (§ 88). But after currents have two factors: (1) Energy set free by union of ions (H and O, Fig. 103) produced by the polarizing current and circulating in galvanometric circuit. This current causing nerve action: (2) Ions

produced by such nerve action unite and set free energy which becomes a current. Hence after currents have different directions.

Extrapolar after currents—energy set free by the union of ions of nerve waste—take a direction according to the polarity of the tissues, and according to the polarity of potentials created in the interpolar region. As the ions (H and O, Fig. 103), unite at the anode the energy set free manifests as an anodal after current followed by a current from the ions of nerve waste. It is evident that these anodal after currents will give different directions to extrapolar anodal after currents; whilst extrapolar cathodal currents follow the latter direction, there being only a current from the ions of nerve waste at this pole. This explains the differential directions of extrapolar after currents.

Electrotonic currents are valuable in demonstrating the difference between the potentials of molecules. They show that a molecule of low potential when decomposed by the galvanic current furnishes results exactly commensurate with the polarizing current, whereas molecules of very high potential when under the influence of the galvanic current show the energy of the current as transformed into the chemic potential of ions, or the potential of heat; but also the independent and inherent potential of molecules as transformed into heat or electric potentials. The importance of this is that it shows when the nerve is excited physiologically, or by other irritants, the same independent energy is set free (§ 153). The only difference being that the freed energy when converted into an electrotonic current is influenced in direction by the galvanic current.

Applications of the galvanic or polarizing current to a nerve produce electrotonic currents as follow:

1. Anelectrotonic currents produced by energy set free by union of ions of nerve waste; and by heat generated by neutralization of the polarizing current at the anode.

2. Catelectrotonic currents produced by energy set free by union of ions of waste.

3. Interpolar after currents produced by energy set free by union of ions resulting from electrolysis of the tissues; and by energy set free by union of ions of nerve waste, the nerve being again excited by the electrolytic current.

4. Extrapolar electrotonic currents, and after currents resulting from energy set free by union of ions of nerve waste.

Furthermore, when tissues are polarized by a sufficiently strong galvanic current, and are at the same time intercalated in another (galvanometric) circuit, the intermolecular ether of the latter is inductively disturbed, as shown by action-currents manifested simultaneously with polarization of the muscle. When it is borne in mind that the potentials of currents, passing through the body, must be neutralized according to the law of forces, it will be readily conceived that the galvanic current sets up inductive disturbances of far reaching character, although these are only manifested when the tissues affected are placed within independent galvanometric circuits.

CHAPTER XV

Trophic Nerves and Gland-Cells

203. When a nerve is in action each physiologic molecule or neuromere is alternately polarizing and depolarizing. Polarization is effected at the expense of dissociation of atoms from the nerve molecule which represents the nerve waste. The atoms dissociated consist of equal or nearly equal valencies of positives and negatives, and they are eliminated from the molecular construction at their respective poles. They are held in the polar areas during the polarization of the molecule (§ 82). Immediately on depolarization the atoms are free to act according to their chemic affinities. In general the freed atoms immediately unite, probably forming carbon dioxide and water—CO_2 and H_2O—with secondary reactions (§ 160). Carbon is considered as a positive element, but its inductive potential is of slight positive quality (§36, § 37), and it may be equatorial having merely passive potential. Thus there are dissociated from the physiologic unit, as a result of the polarizing act, elements which when combined give a resultant which is slightly electronegative. The energy set free has already been considered (§ 160). When this energy becomes heat it has an important bearing on the metabolic changes in the tissues by raising the temperature and pressure.

204. The production of ozone by the electric current is anabolism with an increased potential of concentra-

tiveness (§28, § 33). The ether atoms of the current unite to form an ether molecule—heat—which acts on a molecule of oxygen and disrupts it, as in the first step of electrolysis (§ 51), and the ether is absorbed in the increased interspaces of the atoms or sub-molecules. In the next step the dissociated oxygen atoms attach themselves to other oxygen molecules. The ozone molecule thus formed has an increased potential of concentrativeness measured by diatomic oxygen as a standard of equilibrium, but energy is evolved—ether is set free from interspaces—by the oxygen atoms or ions uniting with oxygen molecules. The reaction is similar to that of sulphur uniting with oxygen (§ 34). It is an instance of oxygen being burned in its own atmosphere. The transformation of energy is as follows: The electric current—atomic ether—is converted into heat—molecular ether—which is momentarily absorbed by the ions of oxygen, but again radiates with a re-enforcement from the interspaces of oxygen when ozone is formed.

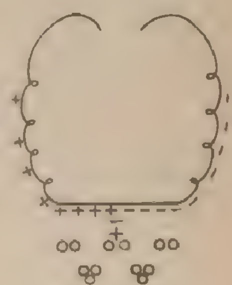


Fig. 104.
Production of Ozone.

205. By lowering molecular potential in the substance of the sun large quantities of ether constantly are being set free. The freed ether disturbs by displacement the equilibrium of matter, and sets up ether activities throughout space. The exposure of a leaf of a plant to these ether activities creates a difference of potential in different parts of the plant, and a current of molecular ether—heat—is initiated from the higher to the lower thermic potential. As an increased resistance is met the ether stream must find lodgment in

the intermolecular spaces in the plant's structure. It selects carbonic dioxide and water as offering the least resistance to molecular change. The enlargement, however, of the intermolecular spaces of these substances is resisted by the plant's tenaciousness and cohesiveness and by atmospheric pressure. Under these conditions what takes place is expressed in the following formulæ:

$$6\,(CO_2) + 5\,H_2\,O = C_6\,H_{10}O_5 + 6\,(O_2).$$

The ether enters the carbon dioxide molecules and disrupts them, and under pressure the carbon is forced into combination with the water, the five molecules of water and six atoms of carbon forming one molecule of starch. The oxygen of the six molecules of carbon dioxide occupies the space that the latter occupied before disruption, but with increased intermolecular ether, owing to larger interspaces (§ 29, § 33). Six atoms of carbon and five molecules of water have been pressed into one with an increased potential of concentrativeness. Carbon being equatorial or positive and water being positive, starch must also be positive. The ether has been absorbed into the induced fields and interspaces of molecules of higher potential. What has taken place is that ether has been depolarized by the loss of molecular potential in the sun, and has been absorbed into interspaces or polarized in the induced fields of molecules of high potentials on the earth's surface. It is asserted that the presence of chlorophyll is necessary for this action to take place. If this is correct chlorophyll then acts as an enzyme (§ 211). The presence of chlorophyll, however, may be incidental and not essential.

206. Although in animal life chemic changes are chiefly katabolic in character, yet there are many important anabolic processes going on in the metabolism. Between the blood or the innumerable storehouses of energy throughout the body and the nerves and muscles, metabolic changes are continually occurring, which can be explained by the law that molecules tend to reform under a lower potential, or the law of equipotential surfaces (§ 8, § 162). Molecules of high potential dissociating by this law, under a certain degree of pressure, and in the presence of other molecules of greater stability, will produce anabolic changes in the latter. In animal organism, evidently under the immediate supervision of the nervous system, certain metabolic changes take place, which in the total are anabolic in character, and which have an additional fundamental principle as a factor in the causality of change. The factor referred to is molecular polarization.

207. *Molecular Polarization.* It has been shown that conduction of nerve force is accomplished by alternate molecular polarization and depolarization (§ 174), and that polarization favors dissociation of the molecule polarized (§ 157). Further, it has been shown that nature by a change in the environment of a fundamental histological element produces phenomena of entirely diverse character (§ 221).

The nerves that supply glandular structure are efferent. Being such, in what way do they differ from motor nerves? There is no reason to suppose that in structure and in the character of the impulses conveyed they differ from other efferent nerves. Moreover, the secreting elements of a gland and the contracting elements of a muscle may be histogenetically iden-

tical, having a common origin. Again, if all efferent nerves convey the same impulses, the summations of these impulses in the muscles and in the glands may have a common principle. There is reason to believe that all efferent nerves produce their differential effects through the common principle of polarization of the physiologic units or molecular elements of the structure acted upon.

Microscopical work conducted recently indicates that the secretory nerve fibers terminate in a plexus between and around the epithelial cells, from which it may be inferred that the gland-cells are acted upon directly by the nerve impulses. These nerve impulses therefore must polarize the units of the gland-cells, just as the sarcomeres are polarized, and during polarization certain positive and negative elements are dissociated. The character of these elementary ions may be judged from the molecular character of the cell structure. The formula of the cell-unit may considered as:—O N P C H +. Sulphur has been added as an element to the base of the muscle-unit (§ 182.) The most negative element—oxygen—will appear at the negative pole of the unit, and the most positive elements—hydrogen and carbon—at the positive pole (§ 160). In fact, the cell body will act exactly as if it were part of the exciting nerve, and the polarization of the nerve and of the gland-cell will in no way differ, only in the larger chemic and physical effect produced on the part of the gland-cell. Neither will polarization of the gland-cells differ from polarization of the muscle-cells, only, in those differential results arising from the fact of the muscle-cells undergoing distortion and compression previous to polarization,

and in the sequential physiologic conditions depending on different environment.

208. The result, then, of nerve action on the gland-cells is dissociation of certain positive and negative atoms from the structure of the cell-unit. The ions eliminated are in the nascent state, and will take one of the following courses:

1. They may combine, forming simple compounds.

2. They may react on salts that may be present.

3. By anabolism they may be incorporated into adjoining carbohydrates or proteid bodies.

The course will be influenced by the character of the proximate material and by the degree of pressure essential to the metabolic change.

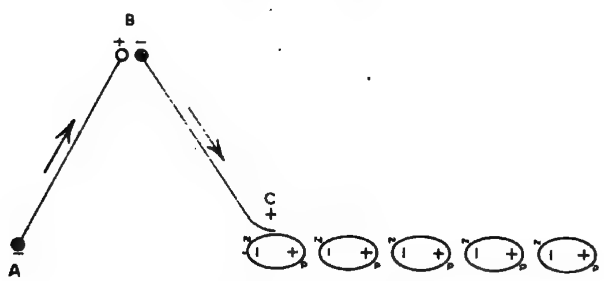


Fig. 105.
Gland-cell Polarization.

209. In Fig. 105, A represents the peripheral terminal of a sensory nerve—the glosso-pharyngeal or lingual; B, a cerebral center; and C, the terminal of an efferent nerve—the chorda tympani—in contact with an epithelium or gland-cell. The spheres indicate polarization of units in the protoplasm of a gland-cell in a ciliary or linear form; the morphology of the cytoplasm being modified in other gland-cells. The polarized potential at the terminal, C, will produce

polarization of the cell; and positive and negative ions, P and N, at the respective poles of the cell-units, are dissociated every time the cell polarizes. These ions are oxygen, carbon and hydrogen. If the gland-cell is bathed in a solution of sodium chloride the following reactions will take place:

$$(Na\ Cl)_2 + O_3 + C + H_2 = Na_2\ CO_3 + (H\ Cl)_2.$$

The above formula will explain the presence of hydrochloric acid in the stomach during digestion, the sodium chloride being furnished by the blood, and the ions, oxygen, carbon and hydrogen, by gland-cell action. If the same gland-cell be placed in the liver and surrounded by glycogen the reactions will be as follows:

$$C_6\ H_{10}O_5 + O_3 + C + H_2 = C_6\ H_{12}O_6 + CO_2.$$

The CO_2 is held loosely in combination with the secretion of the liver, and the glucose is taken up by the blood. In the stomach the sodium carbonate passes to the blood and the hydrogen chloride to the gastric cavity. The question has often been propounded: Why does not the gastric secretion digest the stomach? Simply because it is protected by the ions dissociated during gastric activity; also by the osmotic force of gland-polarization which sends the elements of secretion into the gastric cavity. When this propelling and repelling influence is stopped or weakened the gastric juice attacks the stomach, hence gastric ulcers. Apparently the polar arrangement prevailing in glands is the negative pointing inward toward the blood current, and the positive pointing outward toward the surface, the chemical reactions determining the character of the secretion; but there is no reason why glands should not have the reverse order of polarization, the nerve

filament or other stimulus approaching the gland-cell from a different direction; and furthermore the two orders of polarization may obtain in the structure of the same organ.

If the gland-cell is surrounded by proteids, under the proper degree of pressure, the ions, carbon, hydrogen and oxygen, are forced into the molecule of the proteid and the glyco-proteid mucin is thus formed. The formed material of shells, nails and bones are produced by CO_2 being ionized by nerve action, and the ions uniting with the calcium of the blood.

210. It is clear that anabolism taking place in a gland will be modified by the *intensity of nerve action—number of ions*—by the *character of the substance derived from the blood* which is acted upon by the ions, and by the *degree of pressure* within the gland. The factors modifying pressure are number of ions, arterial tension, and rigidity of the connective tissue of the gland. The chief factor in the differentiation of the blood-elements passing through the gland is the polarity of the gland (Fig. 105, § 1, § 226).

If a nucleo-proteid is placed within the gland, and the pressure regulated by the construction of the gland, and the temperature by nerve action, clearly, the ions will be forced into the molecular construction of the nucleo-proteid. Thus ptyalin, pepsin, trypsin and other enzymes may be produced by a slight differentiated action resulting from a modification of one or more of the above factors. Obviously the nervous system has two distinct functions in connection with glandular action. It regulates the amount of blood reaching the gland by means of the sympathetic; and modifies the elements of the blood passing through the gland by means of cerebral nerves, the modification

being produced by ions, the result of nerve action, which are incorporated into the molecular construction of the blood elements present in the gland, thus raising their potential.

211. *Enzymes.* Enzymes are unorganized ferments. Living ferments, such as the yeast plant and bacteria, are spoken of as organized ferments. The exact chemic composition of enzymes is unknown. They are probably proteids, and consist of carbon, hydrogen, nitrogen and oxygen, and perhaps sulphur or phosphorus. Enzymes have been divided into proteolytic enzymes, amylolytic enzymes, fat-splitting enzymes, sugar-splitting and coagulating enzymes.

The effect produced by the enzymes is not in proportion to the amount of the enzyme. The effect, however, produced increases up to a certain maximum amount of the enzyme, increase of the latter above this point producing no further effect. It is generally believed that the chemic effect produced on the substance acted upon is that of hydrolysis; that is, the molecules of the substance acted upon by the enzymes take up one or more molecules of water.

212. A great many theories have been advanced to explain the action of enzymes and organized ferments. Their action may be explained as follows: Electric induction has already been referred to (§ 65–67), and it has been shown that any polarizable body within the electric field becomes polarized. It has been stated also that the chemic potential of a molecule must have an induced electric or magnetic field (§ 29). It is evident that as bodies are polarized by an electric potential, bodies will be similarly polarized by a molecular potential. It has been shown, and it is obvious, that polarization is a step towards disintegration. Polarization is work

done towards dissociation, and places a potential in the polarized body. The atoms of a molecule polarized are partly dissociated, and are therefore in a position to unite with another molecule with which they may be incapable of uniting under ordinary conditions. Obviously induced polarization is an important factor in the production of physiological phenomena.

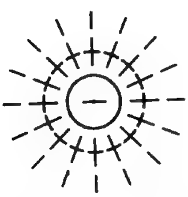


Fig. 106.
An Enzyme and Its Polarized Field.

213. The enzyme-molecule is a body of high potential, probably of negative quality, and therefore has an induced or magnetic field. The molecule H_2O coming within the influence of this field becomes polarized, and when under polarization it is capable of hydrolysis. A molecule of cane sugar, also positive, coming within the magnetic field is split up thus:

$$\underset{\textit{Cane sugar}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\textit{Dextrose}}{C_6\,H_{12}O_6} + \underset{\textit{Levulose}}{C_6\,H_{12}O_6}$$

When the reconstructed molecules leave the induced field others take their place, and this cycle continues indefinitely, or until the enzyme is destroyed by conditions of temperature, or by coming in contact with substances of strong chemic affinity which break it up.

It is possible that the process of hydrolysis effected by enzymes may enter largely into the metabolism of tissues. The polarization of water by molecules of

large potential being work done, which enables the potential of other molecules to accomplish further work. Whether the total work done assumes an anabolic or katabolic character depends on the temperature and pressure. Thus with slight pressure the tendency is towards katabolism, and with greater pressure the changing atoms are forced to become constituents of other molecules—anabolism. It is likely that other substances besides water are polarized by enzymes; thus, in the gastric juice, H Cl may be thus influenced, and pressed into the proteid molecule, resulting in acid-albumen. It is probable that both substances acted upon are polarized in the induced field of the enzyme, thus being prepared for the anabolic process. Enzymes may be either negative or positive in potential, usually acting on molecules of opposite quality.

Thus the explanation of the action of enzymes may be made on the basis of the fundamental principles of attraction and repulsion. According to the law of forces these are: (1) Attraction between positives and negatives; (2) repulsion between negatives; and (3) a limited repulsion between positives, or the impenetrability of induced fields to like forces. In addition, as a supervisor of all reactions there exists the important factor of the molecular spacial equilibrium (§ 150). Differential manifestations of the forces may be stated thus:

1. When a conductor is placed within an induced field of an electric potential the former immediately polarizes. That is, the units of the conductor of opposite quality to the electric potential are attracted, and those of similar quality to the electric potential are repelled. The electric potential exercises a *push*

or a *pull* on all proximate units of the conductor, according to the law of forces.

2. When an unstable molecule approximates another molecule of opposite potential of great intensity, both molecules polarize, their units are attracted or repelled according to the law of forces, and if the push and pull are sufficiently strong chemical dissociation and association occur.

3. When an unstable molecule approximates a molecule of stable character the latter exercises a pull and push on the units of the former with a resulting decomposition of the unstable molecule. The catalytic action of platinum, gold, silver or manganese on hydrogen peroxide is an example of this form of attraction and repulsion.

4. When a mass possessing certain molecular potentials is in proximation with another mass having potentials in a different degree or of opposite quality, the attractions and repulsions of the two masses tend to equilibrate, and if the physicial conditions are favorable osmosis takes place. The units of the two masses mutually exercise a push and a pull, although only the greater force may be manifested.

5. When an enzyme, of inductive negative potential and of a certain constructive stability, is in proximation to molecules of saccharose, $C_{12}H_{22}O_{11}$, and water, H_2O, both of positive quality, and the former of unstable character, the saccharose and water molecules are polarized in the induced field of the enzyme, just as the conductor is polarized in the induced field of the electric potential. The enzyme has the properties of a push and a pull on the units of the molecules of the sugar and the water according to the law of forces. The negative inductive

potential of the enzyme repels the oxygen and attracts the hydrogen and carbon of the sugar, and as attraction exists between these elements cleavage takes place in groups—the elements divide into one molecule of glucose and one of glycogen; but as the polarization of the water and the glycogen, and the temperature and pressure, favor anabolism, the glycogen and water combine, and the molecular spacial equilibrium is maintained, as in similar anabolism in the liver (§ 300). The glucose molecules remain in the induced field of the enzyme until displaced by extrinsic physical action, such as mastication, when the enzyme is ready for further action.

214. *Thyroid Glands. The Thyroids* are glandular structures common to all vertebrates. Histologically they are composed of closed vesicles, lined with a single layer of cuboidal epithelium. The interior of the vesicle is filled with a homeogeneous glairy liquid, the colloidal substance, which is also found in the lymph spaces between the vesicles. The colloidal material is supposed to be taken up by the lymphatics and thus conveyed to the blood. Its composition has not been distinctly defined. However, it has been established by experimental research and clinical evidence that animal health and life depend on the physiologic action of these glands. Blood-elements have been found in the vesicle; and in the lymphatics of the gland Baber has found a viscid substance morphologically identical with that in the vesicle. These facts prove that osmosis takes place from the blood vessels through the vesicle to the lymph channels.

215. Great interest has been excited with regard to the function of this gland, and a number of theories advanced to account for its importance to physiologic

action. Until the chemistry of the gland is better understood no satisfactory hypothesis can be advanced. However, it is reasonable to conclude that the thyroid gland-cell acts fundamentally similar to other epithelial cells: that they are polarized by nerve action; that carbon, oxygen and hydrogen ions are formed; and that by an anabolic process these ions are pressed into other molecules, thus raising the potential of the latter. Evidently electro-positive elements of the blood by osmosis pass inward, are built up to a negative potential by the ions, and are repelled outward by the negativity of the gland and by the osmotic forces of the circulation.

Some of the elementary substances of the blood therefore leave the gland with an increased potential, which is essential to these substances in their function of supplying nutrition to various tissues. Thus they are capable according to the law of chemic equipotential surfaces (§ 8, § 162) to transfer this potential to muscular and nerve tissue. They are ships into which potential has been compressed and which they unload at distant ports.

The economical equilibrium that exists between anabolic and katabolic processes is maintained by raising the potential of blood-elements as they pass through the thyroid gland. On the other hand, the functional elimination of the gland from the animal economy is a disturbance in favor of katabolism.

216. It has been suggested that the ovaries and testicles may have functions similar to the thyroid gland, but this is not supported by anatomical evidence. The following tabulation shows the main points of difference:

GLAND DIFFERENTIATION.

	Thyroid.	*Testicle.*	*Graafian vesicle.*
Osmosis.	From blood vessels through cell to lymphatics.	From lymphatics to tubules.	No osmosis. The pressure is from within outward owing to production of ions (§ 229).
Nerve Endings.	Epithelial cells in vesicle.	Endothelial cells bounding lymph spaces.	Epithelial cells in vesicle.
Ions.	Act on blood-elements.	Act on lymph.	Act on ovum.
Results.	Blood-elements built up in potential by ions and passing into the circulation.	Reactions between ions and lymph salts produce elements which build up epithelial cells and cause their division, the cells passing into the tubules.	Ovum is built up to a high negative potential. The ovum does not multiply owing to absence of blood elements.

Of late various extracts from glands—the thyroid, the adrenal, ovaries, testicles, etc.—have been prepared. They no doubt possess by their molecular constitution a very high potential, which is capable of replenishing the stored energies of muscle and nerve. However, more detailed and exact experiments are necessary before their scientific value can be estimated.

CHAPTER XVI

Animal Electricity

217. Wherever there is chemical action electrical currents, sensible or insensible, are possible. Throughout the organic world nature displays some more or less extravagant development of particular characters with the sacrifice of others. Such specialized development, brought about by the process of evolution, represents a principle present in all organizations, no matter how small. Thus some animals are swift and others strong, some use the anterior extremities as wings; others these as legs; and still others these as arms and hands; ruminants have four stomachs; and man has a vermiform appendix. Some fishes have electric organs; while other animals have "motorial plates" or muscles. In these differential developments nature affords us scope in our microscopic studies; for her amplified manifestations represent a universal principle. The gymnotus or electric eel, malapterurus or sheath fish, the torpedo, the skate, and others have concentrated development along electric lines.

218. The electric eel, found in the marshes of South America, has powerful electric organs. It is capable of giving shocks sufficiently strong to stun if not to kill large animals. The organs are situated immediately beneath the skin, and consist of cells filled with a gelatinous material. They are plentifully supplied with

nerves, which are larger than those belonging to other parts of the body. The poles of the electric organs of fishes seem to be in the head and tail. In some of them the head is the positive pole, and in others it is

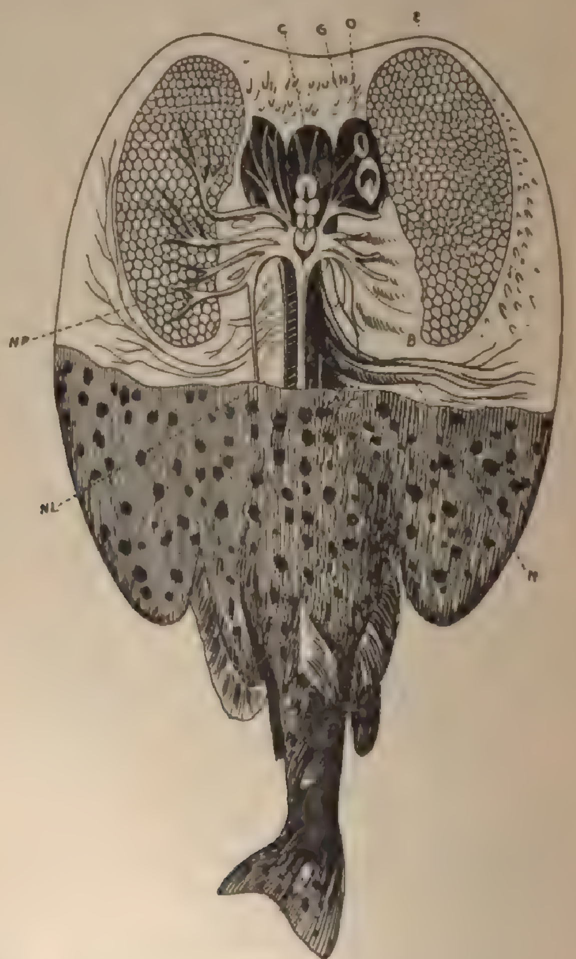


Fig. 107.

The electric fish torpedo, dissected to show electric apparatus (*Huxley*). B, branchiæ; C, brain; E, electric organ; G, cranium; ME, spinal cord; N, nerves to pectoral fins; NL, nervi laterales; NP, branches of pneumo gastric nerves to electric organs; O, eye.

the negative. Humboldt and Callodon held the opinion that electric fishes do not shock each other, and du Bois Reymond's experiments confirmed the correctness of this opinion.

Du Bois Reymond has the credit of investigating this subject. He showed that the current from the electric eel produced electrolysis of iodide of potassium, and that the resulting ions caused a secondary current. The current deflected the galvanometer, produced a spark and otherwise obeyed the laws governing electricity from other sources.

The electric organ of the skate was discovered by Stark. M. Robin describes the minute structure of the discs as polygonal in contour, and arranged in columns with longitudinal septa, an anterior smooth surface and a posterior alveolated. The arterioles are distributed to the posterior and the nerves to the anterior disc surface. The attenuated nerve fiber is described as terminating in a pyramidal or conical body, with its base applied to the disc. The arteries no not enter the disc, but terminate in the alveoli. Wesley Mills confirmed this description of the anatomical arrangement.

219. Professors Burdon-Sanderson and Gotch concluded as follows: In *Raja batis* and *Clavata* there exists an electric organ with electro-motive elements arranged in series, after the manner of a voltaic pile, having a force directly proportional to the number of elements. During the discharge of the organ the caudal end is positive, and the cephalic end negative. Excitation of the spinal cord effects a discharge of the organ, and various reflex centers exist from which the organ can be excited. Professors Burdon-Sanderson and Gotch concluded that the relatively large electromotive force, when compared to ordinary muscle, was

due to the large number of discs, to their being arranged in pile, and to their being able to act simultaneously by virtue of the nervous arrangement.

Professor Gustav Fritsch of Berlin is of the opinion that electric organs are of muscular origin. He states that in the malapterurus the organ seems to have been developed from the skin; that the innumerable nerve branches are derived from two nerve fibers, each leading to a single ganglion cell; and that the structure of the main nerve fiber is suggestive of an electric cable. Professor Max Schultze considers the disc a coalescence of the termination of the nerves, others think that it represents muscular tissue, or that it can be identified with the motor plate. Wesley Mills suggests that it is *sui generis*. The fresh electric organ is neutral but gives an acid reaction on standing, thus resembling muscle; when kept in warm water for a time, it resembles the cerebral nervous system by becoming acid.

220. The author's opinion is that histologically the electric organ is an extreme evolutionary development of the physiologic unit on distinctive lines, and that it is not considered correctly as representing nerve or muscle, only as nerve, muscle and electric organs have a common embryonic origin. Physiologically the electric organ represents neither nerve nor muscle. It differs from nerve tissue in that it is neither sensory nor motor in its function, and it differs from muscle in not having the property of contractility. But, like nerve, it is capable of conductivity if its anatomical environment corresponded to that of the nerve; and, like muscle, it is capable of contractility if its elements were compressed or distorted by elastic tissue, which is an essential condition to muscle function. Comparisons of the same character may be equally made with

the gland-cell. Anatomically and functionally the electric organ bears the same relation to its nerve supply as glands and muscles do to their nerve supply. It may bear a stronger histological resemblance to the axone-hillock than to any other portion of nerve structure. Whether the electric organ is developed from the epiblast or from the mesoblast has not been ascertained; nor does it seem to have been determined whether its proteid contains sulphur or phosphorus. The properties pertaining to *rigor mortis* seem to be absent. The evolutionary path of the electric organ appears to be distinct, and coalesces with that of no other structure. The physiological electrical idea is distinctive and independent, and the anatomical and histological classification should conform to the physiological division.

The physiologic unit of the electric organ has very high potential. It has an atomic construction of great numerical potential; and the character of the atoms is potentially large in its negativity (§ 20, § 152). The potential sum has been stored under essential conditions of temperature and pressure (§ 161); the cell being surrounded by connective tissue giving a resisting pressure, and being furnished with an abundant supply of blood, necessary conditions for anabolic intensity. Obviously each molecule or each disc is a storehouse of concentrated potential of the same character—differing only in degree of development—as the potential of nerve or muscle.

If there is arranged within a circuit a large number of cells or high potential molecules, in pile form, as in the voltaic battery, it is evident that there exists the elements essential for the production of an electric current or explosive discharge. If each of the cells has a

nerve connection which acts as a means of exciting it simultaneously with others, it is obvious that the current may become a shock from the explosive discharge. The cells polarize, carbon, hydrogen and oxygen ions are dissociated, these combine and form simple compounds, and the freed energy is transformed into electricity. This is identical with the action-currents of muscles. A current of rest also may be furnished by the nutrient elements being placed within a circuit, but in this case no nervous connection is required; and as the nerves are well developed action currents no doubt are the type of currents from electric organs.

The structural arrangement by which the circuit is completed seems in doubt. The cells are undoubtedly connected by some conducting material through the surrounding cellular tissue. The organ is placed near the skin, which seems to be a non-conductor; this we infer from the animal not being affected by electric shocks. The skin opposite to the poles by reflex action may be made pervious to water, thus becoming a conductor. The water will then complete the circuit. The greater part of the current will pass through any body immersed in water, and placed within the circuit, if the body is a better conductor than the water. Thus the bodies of animals, being better conductors than fresh water, will receive the shock.

When there occurs a chemic analytic reaction, like zinc and sulphuric acid uniting, as in a galvanic cell, the reaction is accomplished with the evolution of heat. When a muscle contracts, or when a nerve is excited to action; or when any one of the numerous katabolic changes in animal organizations takes place, the action is associated with the production of heat following union of the ions of waste. If the point of production

of energy is part of a circuit, and the substance in which the energy is stored is polarizable—having a terminal difference of potential—when the energy is freed, then the energy—polarized ether (§ 42, § 43)—can follow one of two courses. It may dissociate and the atoms follow the circuit as an electric current; or without dissociation it may manifest itself as heat at the point of emission. The energy will always follow the course of least resistance (§ 153).

The high potential molecule of the electric cell is polarized under the influence of nerve force, under polarization some of the atoms dissociate and form molecules under a lower potential (§ 158), thus setting free energy which manifests itself under the conditions present as electricity.

221. Commencing with the same histological unit the neuro-musculo-electro-glandular cell or unit fundamentally constructed on the same plan—a molecule of high potential—nature stretches the units in line and makes use of their property of conductivity; she places others in tiers, compresses or distorts them by an elastic sheath, and for her purposes calls forth the common property of all matter, under certain conditions, of assuming the spherical form, hence contractility; she arranges them in pile form placed within a circuit, and behold she has an electric current; or by a modification of arrangement, from the ions produced she coustructs a molecule of extreme potential—an anabolism. In all of this nature uses a high potential molecule, polarizable at the will of a central nervous organization. When the molecule or cell is polarized, whether there is manifested the property of conduction by vibrations, whether a physical movement of a body is accomplished, whether the shock of an electric cur-

rent is felt, or whether a cell of the blood emerges from a gland loaded with potential, depends on the placement, connections and surrounding conditions, and not upon an alteration of principle in the polarizable molecule or cell of high potential.

The following partial classification of function is made:

1. Function depending directly on the polarization of the unit:

(*a*) Propagation of polarization—conductivity in nerves, muscles, glands, leucocytes.

(*b*) Modification of form by polarization—contractility in muscles, leucocytes.

2. Function depending on results of polarization:

(*a*) Ions of waste uniting with other molecules —metabolism in glands.

(*b*) Ions of waste uniting and freeing energy which is transformed into electric currents—property of electric organs.

CHAPTER XVII

Cell-Movements

222. A cell, such as the white blood corpuscle, has a high molecular potential, and is sensitive in a high degree to surrounding attraction and repulsion-influences. The various electric currents of the body and osmotic forces direct its course of movement. That the electric currents of the body are important factors in organic motory changes is proved by ciliary action; and by the slight galvanic action required to move spermatozoa (§ 237), and to produce electrolysis. A slight current will have cataphoretic effect. When substances of high potential are placed where there is slight resistance to their transference, as in fluids or semi-fluids, the movements will be effected by very small currents. That these currents exist in the human body there is no reason to doubt. Chemic action taking place in a part of the body sets free ether that has either to overcome local resistance and radiate as heat, or travel as electricity to a more distant part and there radiate under less resistance. The course of least resistance will always be followed.

223. The white blood-corpuscle consists of cytoplasm and a nucleus. There is no nucleolus. The blood-corpuscle is generally spherical in shape, but has the power of changing its form, a characteristic which has been described as amoeboid. In locomotion the cor-

puscle sends out filamentous processes—pseudopodia—which envelop particles in the surrounding medium. When the filaments are withdrawn the particles are lodged in the substance of the cell. The protoplasm contains granules which often exhibit highly refractile properties. The granular substance and the intervening hyaline substance seem to differ in their relative proportions, and also in absolute amount, giving the appearance of many kinds of cells. Chemically the protoplasm of the colorless corpuscle shows the presence of nucleo-proteid and globulin, with fat and a small amount of glycogen.

Assuming that the nucleolus is a molecule of great concentrative potential (§ 242, § 243) built up under an essential degree of pressure, it is clear that under changed conditions it is extremely sensitive to disintegrating influences. It is obvious that a removal of pressure will favor the breaking up of such a large molecule, more particularly as its inductive potential is of negative quality (§ 135). During the constructive period of the cell the nucleolus, like other functionating units, may give off ions which are impressed into nuclear elements, and these, having gained a potential of similar quality to that of the nucleolus, are repelled from the nuclear area to form molecular elements or units in the cytoplasm. In the leucocytes, in the cells of unstriped muscular fibers, and in certain other cells we find what is evidently the remains of a nucleolus and nucleus. Changed conditions have allowed molecular dissociation to take place; they have performed a function, and have become inert and in some instances have died, the resultant particles remaining within the nuclear wall. In other cells, such as the ganglionic

cells of neurones, the nucleoli continue to have functional activity.

The functional properties of the colorless corpuscle reside in the material of its cytoplasm. This no doubt consists of molecules of high negative potential which have been built up during nuclear activity (§ 245). They are sensitive in a high degree to the least vibratory modification of surrounding media, just as the physiologic unit in the optic neurone is sensitive to light vibrations. The universal rule that the more solid element is surrounded with less solid plasma applies to the protoplasm of the leucocyte. The more solid element is the physiologic molecule, and the plasma occupies its vibratory induced sphere. The former has a potential of negative quality and the latter is composed of material of electro-positive character (with oxygen in its molecular induced fields), some of which is nutritive.

Physiologic units in the colorless corpuscles perform their function, as elsewhere, by means of polarization-waves. The units being negative in potential, the corpuscle is excited by the alkalinity of the blood plasma. The leading off point is negative, and the opposite end is positive. The units when polarized must be supplied with associating molecules of polarization, and the polarizing act must be accompanied with the production of ions split up from molecular nutriment. What becomes of these ions, and from what source is the nutriment derived? Within the cytoplasm are found molecules of glycogen and proteids. It is probable the ions hydrogen and oxygen act on glycogen molecules, converting them into glucose; and the glucose in turn furnishes nutritive molecules to the physiologic unit (§ 260). It may be

the same with proteids found within the cell. When the nutrition is exhausted the cell dies, its life being about the same in duration as that of the spermatozoon. When the cell is broken up the molecules of the cytoplasm may become the globulins and nucleo-proteids of the blood, and these again may be the elements of repair in injured tissues, laying the foundation of the physiologic units of such structures as the nerves or muscles.

The movements of the colorless corpuscle having, as their principal factor, polarization-waves passing through molecules of high potential, are fundamentally the same as waves of contractility and conductivity manifested in muscles and nerves. They are also the same in principle as movements in spermatozoa. The difference is in the morphology and environment of the cell. It may be concluded that as the cell moves along with the blood current it is stimulated posteriorly, the plasma pressing more distinctly on this part of the surface, just as the cardiac nerves are stimulated by the blood plasma during diastolic fullness. The stimulating point being negative, the distal ends of the waves are positive. When the cell is at rest it is attracted through its negativity; when polarized the positive pole directs its course, thus differentiating from the sperm movements. The following extrinsic forces must influence the cell: (1) The blood current; (2) the induction of electric body-currents; (3) the osmotic attraction of polarized tissues; and (4) the attraction of blood-molecules.

The incorporation into the mass of the cell of adjoining material, such as coloring matter, must be accomplished by the attraction of opposites, and consequently is not nutritive in character. The pseudopodia

must be sent out during polarization, the absorption and attraction of particles must take place during depolarization and retraction. The terminals of pseudopods, being positive, will point toward negative tissues and to the negative pole of body-currents. Thus the leucocyte moving along with the blood current during polarization will have its positive pole pointing toward the wall of the vessel which it pierces; as its course is checked the stimulus of the blood becomes a greater excitant. The pressure of the blood, electric induction, osmotic attraction, one or all, direct the course of the corpuscle during peristaltic movements; the stored energy within the cell supplies the potential for the movements; and the alkalinity of the blood plasma gives the initiatory stimulus. The movements do not differ fundamentally from those of spermatozoa only as regards the leading off point of the wave and the morphology of the cell; neither do they differ fundamentally from nerve or muscle waves. The leucocyte pierces the wall of the vessel by the force of its polar potential, the adhesive properties of the elements of the membrane are relaxed and brought under the dissolving force of the leucocyte just as the nuclear membrane disappears during mitosis.

224. Certain cell-bodies have to and fro movements without change of relative position. They are free nuclei, with spots which take on a deeper stain than the surrounding chromatin and which indicate nucleoli. They have no cytoplasm. The different cocci are the best known types of this form of cell. A coccus is potentially one body, consisting of a dynamic center with its induced field. Its constituents are incapable of propagating wave-motion, being under the influence of a center having greater potential, consequently they

move as one body (§ 245). The Brownian movement is a vibratory act without propagation. It is said to be non-vital in character, and it is true that non-vital particles with sensitive potentials and in proper media will respond to external excitations; but these movements, common to organic or inorganic material, are strictly commensurate with the extrinsic excitations, and consequently accomplished without intrinsic waste. Now cells with a limited amount of stored nutrition and whose units vibrate—polarize and give off waste—run a limited vital course. The question presents: Is not the Brownian movement a vibratory act, accompanied with molecular polarization and consequent waste, sequential delimitation of the life of the cell, and analogous to the vibratory act of an initiatory unit of a fibril through which an impulse is passing? If these independent nuclei have a limited age in media which do not supply nutrition and in which they manifest the vibratory movement *in situ*, then the evidence surely points to the Brownian movement being of vital character.

Osmosis

225. Osmosis has been treated of previously, but there is one feature of osmotic action that requires further notice. The fact that one secretion being alkaline and another acid has never been satisfactorily accounted for. The presence of hydrochloric acid in the gastric juice has been already explained (§ 207, 210), but the acidity or alkalinity of other secretions evidently depends upon other factors than merely the production of an acid at the point of elimination.

It has been shown that carbon and oxygen are set free by nerve action, and that under certain conditions

they form carbon dioxide. It is found that this product —CO_2—exists in the saliva and bile, which are alkaline in reaction; but it does not exist in the gastric juice, which is acid; but the blood becomes more alkaline during digestion. It is probable that carbon dioxide formed during this act is sent into the blood by osmotic action as sodium carbonate.

The laws that govern the direction of carbon dioxide therefore are evidently those that determine the reactions of most secretions. The principles of simple osmosis do not explain why different directions are taken by this product; why in one case it will seek the blood and in another take an opposite direction. When it is considered that a small current serves to produce osmosis it will be readily seen that the currents of the body will influence the direction and character of the osmotic stream. It is important to note that positive elements go towards the blood notwithstanding that the quality of the latter is also positive, thus proving that osmosis has a factor other than those governing diffusion of liquids in mere contact. On the other hand when an electro-positive substance as blood is separated by a membrane from an electro-negative substance as air, the blood constitutes the electro-positive pole and the air the electro-negative, on the basis of the fundamental identity of electric and molecular potentials.

226. It is known that individual parts of the body are positive or negative when compared to other parts, and that in all parts the chemic potential exists which can be converted into an electric current which may influence osmosis. If for instance nerve action furnishes a potential which charges the terminals of neurones either positively or negatively, these charges will exer-

cise attractions and repulsions which must influence the character and direction of an osmotic flow.

When chemic action takes place with the evolution of heat—ether from induced fields—there is a resistance to its radiation. As the whole body is made up of conductors of comparatively different resistances, as the radiation of heat meets with less resistance at the surface than in the interior of the body, and as there is a difference of temperature between the surface and the interior, it is evident that electric currents will be formed as in the thermo-electric cell (§ 103). It is therefore reasonable to suppose that these currents cause electrolytic and cataphoretic actions and consequently an acidity and an alkalinity at different points of the body; also, as carbon dioxide is a product of nerve and gland action and as a slight electric current will determine its course, it is evident that its osmotic direction is an explanation of the different reactions of secretions. Moreover the glands, like the muscles, must have differentiated poles during action. The placement of a nerve terminal towards one or the other end of a gland will determine its differential polarity; the leading off point being negative, the end of the gland furthest from this point will be positive and the nearest end negative (§ 190). The positive end of a gland pointing to the surface will give an acid secretion; and the negative end pointing to the surface will give an alkaline secretion. The carbon and oxygen ions produced by gland cell action will react on the blood-salts, and the resulting carbonates, being electro-positive, will seek the negative pole of the gland, making the blood more alkaline, or giving the secretion an alkaline reaction according to gland-cell polarity. When the gland-cells are polarized a stream of electro-negative

material will pass toward the positive pole of the gland; and towards its negative pole a stream of electro-positive material; and the direction of the osmotic streams, as to their inward or outward course, must accord with the polarity of the gland and the electro-positivity or electro-negativity of the moving material.

In a complex structure, such as that of the stomach, the glands seem to have differential polar directions—one directing an alkaline stream outward and another directing it inward. On the other hand there is the chemical complexity of the blood-serum which, although always alkaline, no doubt varies in the intensity of its reactions and in the character of its chemical constituency in different localities. Thus, although the ultimate ions dissociated from physiologic units are constant in character, their reactions on blood-elements will possess a delicate discrimination governed by variation in temperature, pressure, distances, and potentials. Hence carbon dioxide set free by gland-action may fail to react on blood-elements, and pass to the positive pole, and again it may react and as a carbonate pass to the negative pole of the gland. Thus by a system of glands differentiated in polar direction, and by an intricate metabolism, nature builds up and tears down, now swerving to the positive side of equilibrium, and then to the negative side, until finally evolving a product exact in molecular potential and definite in essential physiologic capacity. It must always be borne in mind that a vital fluid consists of both positive and negative elements, now the positive elements taking the lead and giving character to its reactions, but carrying within their molecular induced fields matter of negative character; then the negative elements taking the lead, with negative reactions and carrying positive material within induced fields (Fig. 115, § 243).

CHAPTER XVIII

Reproduction

227. It is not within the province of this work to enter largely into this subject, but there are many physiologic problems as yet unsolved, some of them admittedly insolvable by ordinary experimental methods; it is therefore clearly a duty to collect the physiologic facts; and, in the light of electric science, to set forth the fundamental laws governing the various phenomena presented.

Reproductive Organs. Only such anatomical and physiologic facts will be referred to as are necessary to the discussion of the subject.

Female Organs. The *vagina* is lined with pavement epithelium, and the vaginal secretion is usually acid.

The *uterus* is lined with epithelium of the columnar ciliated variety, except in the lower half of the cervix, where it is stratified and non-ciliated. In women and other mammals the direction of the ciliary movement is towards the os uteri. The secretion is viscid and alkaline.

The *Fallopian tubes or oviducts* open into the peritoneal cavity. One of the processes or fimbriæ is attached to the corresponding ovary and is grooved. The length of the Fallopian tube is from three to four inches and the uterine opening is comparatively small. The tube has a longitudinal and circular coat of muscular fibers,

the longitudinal extending into the fimbræ. The tube including the fimbræ is lined throughout with ciliated epithelium, the ciliary current being towards the uterus. The mucous secretion is alkaline. The function of the oviducts is to convey the ova from the ovaries to the uterus; the spermatozoa also travel within the tube in the opposite direction, and the union of the two takes place, as a rule, within the tubes.

228. *The Ovaries*—testes muliebres (Galen)—are modified glandular structures, and their physiologic use is the production of ova. They are each about an inch

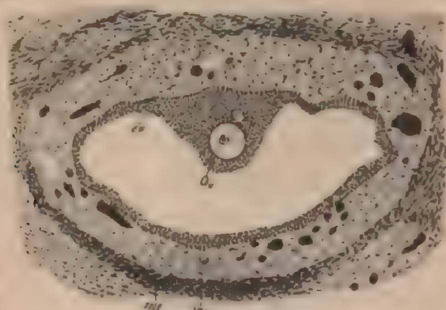


Fig. 108.

Graafian Follicle: OV, ovum in discus proligerus; EP, follicular epithelium; THE, external theca; THI, internal theca with blood vessels (*Sobotta modified*).

and a half in length, three-quarters of an inch in width, and about one-third of an inch thick, and weigh from one to two drachms. The structure of the ovaries consists of a number of Graafian vesicles imbedded in the meshes of a stroma and invested by a serous covering derived from the peritoneum, the epithelium of which has been named *the germial epithelium* of Waldeyer. The *stroma* is abundantly supplied with blood vessels; and is much condensed on the surface of the organ, where it was formerly supposed to be a distinct fibrous covering called the tunica albuginea.

The Graafian vesicles consist of an external fibro-vascular coat—the theca—connected with the surrounding stroma by a network of blood vessels, and an internal coat the ovicapsule, which is lined by a layer of polyhedral epithelial cells, called the *membrana granulosa*. In the interior of the vesicles is a transparent albuminous fluid, the liquor folliculi.

In the part of the mature Graafian vesicle nearest the surface of the ovary, the cells of the membrana

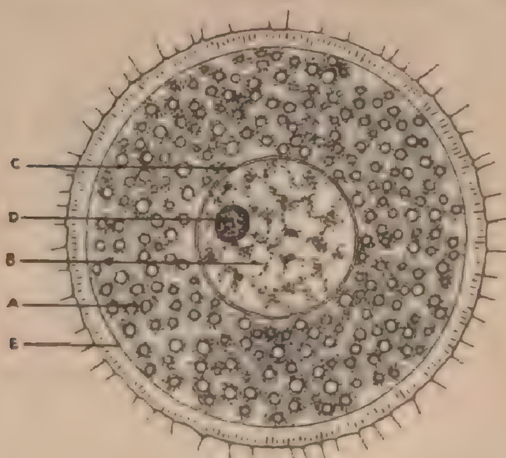


Fig. 109.

Typical Cell—ovum of cat: A, protoplasm; B, nucleus; C, nuclear membrane; D, nucleolus; E, true cell-wall, closely applied to the surrounding secondary envelope, the zona pellucida.

granulosa are collected into a hillock which projects into the cavity of the vesicle. This mass of cells is called the discus proligerus, and in this the ovum is imbedded. The ova are formed from the germ-epithelium on the surface of the ovary, the cells becoming enlarged and involuted, forming little depressions. As they sink deeper they become enclosed by the stroma, which ultimately cuts them off from the surface. The

germ-epithelium is thus enclosed in a cavity: the future Graafian vesicle. The cells which surround the ovum, by their division, give rise to the numerous elements lining the follicle, and were originally derived from the *germinal epithelium.*

The ovum is a spherical body surrounded by a distinct membrane, the *zona pellucida*, enclosed in which is the vitellus or protoplasm. The germinal vesicle corresponds to the nucleus of the ovum and contains the germinal spot or nucleolus. The blood vessels and lymphatics are numerous in the ovary. Entering through the hilum and passing through the medulla, they have been traced in the cortex to the walls of the larger follicles. The nerves are cerebro-spinal and sympathetic. They enter the cortex and have been *traced into the envelope of the Graafian follicles.*

229. *Construction of the Ovum.* The ovarian nerves have been traced into the covering of the larger Graafian follicles. There being no physiologic reason for the cerebro-spinal fibers terminating in the follicular theca, it is only reasonable to conclude that fine twigs penetrate the envelope of the follicles and terminate in contact with the cells of the membrana granulosa. By so doing they correspond in their mode of termination with the nerve filaments in other glands and in the muscles. The cells surrounding the ovum are thus brought under nerve action, in fact are the real terminals of the cerebro-spinal fibers, and thus receive their impulses. Such being the case, there must be alternate polarization and depolarization of the epithelial cells of the membrana granulosa in response to the cerebration of the mother.

230. An important factor in the production of ovarian anabolism is found in the pressure resulting from

the dense and unyielding character of the fibrous tissue of the ovary. Thus a metabolism that would otherwise become katabolic and diffuse, results in anabolic intensity (§ 159, § 161). The results of nerve action on the epithelial cells of the membrana granulosa are the production of ions, as in the case of muscular or gland polarization (§ 208, § 182—184). The tendency of these ions is to form simple combinations with the evolution of heat, but this is rendered impossible by the resisting pressure of the fibrous tissue. The ovum, situated in the midst of an aggregation of cells of the discus proligerus, and being the only cell not connected with nerve filaments, becomes enveloped in an intense potential, and as the ions continue to develop by nerve action they are forced into the molecular construction of the ovum.

It has been generally supposed that the ovum is built up by osmosis. This is impossible, as osmotic action is impelled by a higher becoming a lower potential, and to build up the high potential ovum by such action is similar to making water run upwards. Osmotic attraction could not differentiate the ovum from the cells of the membrana granulosa.

The nutrition of the cells of the discus proligerus is probably furnished by osmotic displacement. Having lost potential by polarized action, they regain it by the combustion of molecules of high potential from the blood; and later, after the development of the follicular theca, it is possible that this takes place entirely through the nerve filaments, the entire nutrition of the ovum being derived through a nerve route, and not directly from the blood (§ 238). In this case the cells of the membrana granulosa, being in direct connection with the nerve filament, receive by displacement, as nutrition,

molecules of carbon dioxide, CO_2, and H_2O, or hydrogen carbonate, H_2CO_3, through the neurones, and by polarization convert these molecules into ions of carbon, hydrogen and oxygen, which partially or wholly are associated with and potentially build up the ovum. In the early history of the Graafian follicle, before the complete development of the basement membrane, osmotic communication with the blood remains intact, but it is quite possible, toward the end of its history, that the Graafian follicle presents the anomaly of a part of the body being nourished through the nervous system. A blood supply is necessary in laying the base of the cell, but afterwards its negative potential may be maintained or raised by ions produced by nerve action (§ 208), or by molecules of nutrition supplied by displacement through a neurone (§ 238). The development of the follicular theca marks a change in the nutrition of the follicle and hence cell-segmentation ceases. As the follicle matures it gradually presses on surrounding tissue and seeks to escape by the path of least resistance. This implies a tension from within, and points to osmotic tendencies being from within outwards.

231. *Maternal Psychic Influence.* If vibration is the medium through which psychic force is transformed into material manifestations, then we have a key to maternal impressions on the ovum. As a thought plays upon the molecular vibrations of a cerebral cell the vibrations are transmitted along the fibril and polarize an epithelial cell in the discus proligerus, and in consequence of such polarization an ion is produced. The ion quivering in harmony with the oscillatory movement of the initiatory psychic action is incorporated into the molecular construction of the ovum.

Like a ray of energy from the surface of the sun the vibration travels until it meets a certain resistance, when it becomes localized (§ 205). The atom so incorporated may be displaced, but its vibratile influence by a modification of cell-vibration remains for all time, and manifests itself by sympathetic responsive action at various periods throughout the life of the ovum, or of the individual of which it is the primary unit.

232. When a Graafian vesicle breaks, the Fallopian fimbriæ are bathed by the liquor folliculi. This fluid excites the sensitive fimbriæ, which contract, and the ovum is drawn into the Fallopian tube. This excitation appears to be similar to the action of alkaline fluids on the spermatozoa.

Within the tube the ovum rides on the vibratile waves of the ciliated epithelium of the tube. Cilia seem to be distinct electric bodies of extremely delicate sensitiveness, and indicate by the direction of their vibrations the direction of the current in the part of the body in which they are situated. When it is considered that the human organism is made up of cells of very high potential, and that chemic action is going on constantly, it will be understood how these delicate filaments are bent toward the direction in which their potential is attracted. From the analogy that exists between the ciliary filaments and tails of spermatozoa (§ 234) it is probable that cilia are excited at their attached ends by the secretion at the small nodule from which they arise. The excited points become negative (§ 186), which would make the free ends electropositive.

The ovum has an intense negative potential. Its chemistry is indefinitely known, but probably it exceeds a quantitatively equal amount of carbon dioxide in its

negativity. The negative ovum therefore attracts the positive free ends of the cilia. When there are a number of cilia in contact with the ovum they have sufficient force to rebound in the direction of their natural vibratile movement, carrying the ovum along with them. The ovum then attracts others and the process is repeated. If there were placed in line an indefinite number of ova passing over cilia there would be a demonstration of the method of electric travel in the galvanic current (§ 46), a method we have called trapeziform. It takes from four to six days for the ovum to reach the uterus.

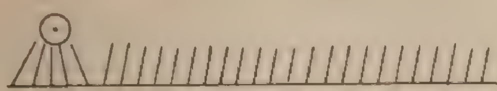


Fig. 110.
Representation of an Ovum riding on Ciliary Epithelium.

233. *Male Reproductive Organs.* For the purposes of this work it is only necessary to refer to certain anatomical structures of the male reproductive organs. From the same fundamental principles and histological elements, from which the ovary is developed, nature, by altering the environment and conditions, produces differential results.

Each semeniferous tube is connected with the basement membrane, which is divided into two layers: (1) a delicate homogeneous layer on which rest the epithelial cells; and (2) a layer of endothelial cells, which gradually pass into the interstitial tissue and bound the lymphatic spaces. From the epithelial cells the spermatozoa are developed. The nerves of the testes are distributed to the surfaces of the semeniferous

tubes. They have not been traced to the epithelial lining of the tubes.

The layer of the endothelial cells in the testis is the analogue of the membrana granulosa in the Graafian follicle, and the cells of both are the real terminals of the cerebro-spinal nerves. The placements of the membranæ propriæ are important, and indicate the fundamental causes of differentiation of ova and spermatozoa. In the ovary the membrana propria of the follicle, which is comparatively dense, is placed between the terminal nerve cells—membrana granulosa—and the circulation; in the testis the membrana propria, which is delicate, is placed between the terminal nerve cells—the endothelial layer—and the epithelial cells, from which are derived the spermatozoa. In the Graafian follicle the nerves undoubtedly pass through the basement membrane, in the testis they do not. The endothelial layer of cells border on the lymph spaces.

Now, after the formation of the basic membrane if any part of the blood reaches the interior of the Graafian follicle it must consist of the more diffusible elements; but, as we have already suggested, it is probable that it is only through the nerve filaments that such elements are conveyed to the follicle, and it is probable that osmosis is outward and not inward. Membranes are formed of elements which are free to act on their own polar attraction and their placements are at the margins of induced spheres.

The endothelial cells in the testes, acted on by nerve filaments, produce ions, hydrogen, carbon and oxygen. The action of these ions on the lymph salts results in the formation of other salts and the setting free of *secondary ions*, electro-negative compounds of nitrogen

and phosphorus. At the point of formation these nascent elements and others are divided into two classes, which, owing to the polarity of tissues, take different directions. The electro-positive compounds go inward and are carried along with the lymph stream, and the electro-negative outward to the tubuli seminiferi. The current-direction is the same that obtains in the stomach, at least in some of its glands, but there is this difference: The osmosis in the stomach is from the blood vessels to the gastric cavity, whilst in the testicle it is from the lymphatics to the tubuli. The osmotic current which passes toward the tubuli is in the main electro-negative; it however contains electro-positive bases chemically united with stronger electro-negatives. Compounds of the proteid class, such as nuclein, built up to an electro-negative character by the ions, are included. The latter become the chromosomes of the cells. It does not appear that hydro-carbons pass outward. They are electro-positive and incapable of being qualitatively changed by further anabolism. From the material of this osmotic stream are constructed the differentiated elements of the spermatozoon.

What are the electric qualities of the elements of the spermatozoon? An axial fiber which is electro-negaative, the units of which are surrounded by elements of nutrition which are electro-positive; and an end-knob or centrosome which is electro-positive, surrounded by chromosomes which are electro-negative, the latter having electro-positive fields. The spermatogenetic cells are furnished with all the nutrient elements of which they are themselves composed. The essential elements for subdivision are loosely held, and the pressure and temperature are such that these ele-

ments unite readily with the cell. Division takes place because the necessary nutriment is at hand, and the number of times the cells divide is regulated by the proportionate amount of nutrition. The shape of the cell accords with the mould, each individual particle following the course of least resistance, and each, according to its weight and potential, travelling its allotted distance. As the material reaches the tubule the osmotic force and pressure decrease. As the current slows elements are precipitated, the heavier and positive first, and afterwards the lighter and negative. Thus calcium or other bases—carried in the induced fields of negative molecules—form the end-knob, and the more negative elements form the tail. Each molecule of high potential, however, is surrounded by its induced field in which smaller molecules of opposite quality are located. The position of spermatozoa in the tubule supports this explanation, the head approximating the membrana propria.

The nucleolus being formed by precipitated bases of electro-positive quality, and the nucleus being formed of negative material—chromosomes etc.—consequently between the material of the nucleus and the nucleolus there is attraction. The chromosomes of the spermatozoon have been built up by the product of action of the cells of the endothelium, and in this respect differ from the chromosomes of the nerve or other cells which—after the formative stage—are built up under the potential of their own nucleoli, which is negative, and are then repelled from the nuclear area. The units of the axial fiber are negative and are surrounded by positive nutrient material carried along, in their induced spheres, from the lymph.

The essential differentiation in the spermatozoon and ovum is the respective electro-positivity and electro-negativity of their nucleoli, an important factor in this differentiation being the lessened pressure in the tubuli from their being open, and the increased pressure in Graafian vesicles from their being closed. The elements of the nuclei and cytoplasm of the ovum and sperm are mainly negative, being constructed in their later metabolism by the action of the cells of the endothelium and membrana granulosa. In consequence of the material of their nuclei being of the same quality the nucleus of the sperm is added in bulk to the nucleus of the germ, there being no chemic union or diffusion. It is possible that the nucleoli of the first layer of spermatogenetic cells are negative, and that as they proceed outwards they are joined by the precipitated bases and converted into a positive potential. If the conditions of the tubuli seminiferi were such that the cells of the second layer could escape without further subdivision the nucleoli might be negative as in ova and as in nerve cells—hence impotency.

The main factors in the subdivision of cells as viewed from testicular conditions seem to be: (1) Lymph osmosis; (2) ions produced by action of cells and acting on lymph; (3) polar differentiation of secreting cells so that the negative stream goes toward the dividing cells; (4) regulation of the pressure so that there is a rearrangement of the constituents of the osmotic material according to their own polar attractions. The conclusions are inevitable that division or non-division of a cell is owing to the character of its nutrition, and not to the quality of the cell; that division is not exclusively a physiologic property but also a physical property, and that any molecule will divide under proper

conditions; and that extrinsic pressure is an important factor in division as shown in the various decrements of pressure in a vacuum tube.

Granting that the general formula of the cell-molecule or physiologic unit is: $-O_nN_nP_nC_nH_n+$, it is evident that if it is fed with oxygen, carbon and hydrogen, it may be built up to a high negative potential as in the ovum, or it may functionate as in a nerve or muscle, but it is equally evident that it cannot reproduce from such nutritional elements, except at the expense of its stability. If it is fed with compounds of oxygen, nitrogen, phosphorus, carbon and hydrogen under the essential conditions it may reproduce a unit similar to itself. Furthermore if to these elements are added a positive element such as calcium or sodium, it is obvious that reproduction may take place with a change in the character of the unit. It is also obvious that if division take place a number of times and the unit fed with the positive element that its quality may be entirely changed from a negative molecule to a positive one. This is exactly what must take place in the metabolic changes that convert the spermatogonia, evidently having negative nucleoli, into cells with electropositive nucleoli and having fecundating properties. Beginning with two cell-molecules qualitatively identical nature feeds one with a few elements, in the main negative, and constructs an ovum-nucleolus, and feeds the other with elements, in the main of a positive quality, and converts it into a sperm-nucleolus; and the relationship of the two is as that of water of crystallization and the crystallizing salt—the one is coefficient to the other.

When mixed material as the lymph is divided by means of osmosis induced by the polarity of tissues,

molecules of high potentials are more sensitive to the inductive influence than molecules of less potentials, but these high potential molecules have within their induced fields smaller molecules of opposite potentials, therefore in any case there is a mixed osmosis. In osmosis of electro-negative material the larger molecules are negative, but within the induced fields of these there are many smaller positive molecules. This is exemplified by the electric induction of spermatozoa which are carried to the positive pole, although they have many positive molecules in their structure.

Fig. 111.

A human spermatozoon: A, head or nucleus; B, end-knob, centrosome or nucleolus; C, middle piece; D, flagellum; E, end-piece. The flagellum evidently consists of an axis covered by indifferent material or sheath but exposed at C and E.

The semen as ejected consists of the secretion of the testicle, diluted with that of the seminal vesicles, prostate, Cowper's glands, and the mucous membranes traversed. In the concentrated and probably neutral or electro-negative fluid secreted by the testicle and epididymis the spermatozoa show no movement. The movements commence when dilution takes place by the secretions of the other organs mentioned which have a positive reaction and which furnish a physiologic stimulus to the negative axial fiber of the spermatozoon. This fact is typical of initiatory stimuli to the pneumogastric afferent fibers in the heart and lungs by the alkalinity of the blood serum.

234. *The spermatozoa* are elements highly specialized, having intense potential and tenacious vitality. A mammalian spermatozoon is made up of the head, middle piece, and tail. The head terminates anteriorly in a blunt rounded extremity, and is the modified nucleus of the cell. The middle piece is connected anteriorly with the head by an enlargement, the end-knob, which is considered to be the nucleolus or centrosome, and fades posteriorly into the delicate caudal filament. The center of the flagellum is occupied with an axial fiber extending from the head to the extreme end of the tail, where it alone forms the terminal segment. It also forms the articulation between the head and middle piece. The cilium or tail is the cytoplasm.

The vibratory action of the spermatic filament continues for hours and even days. The opinion has been entertained that they will retain their powers of fecundation in the female generative tract for weeks. The exact chemistry of the spermatozoon is not known; it is, however, composed largely of nuclein, a substance whose potential has been estimated to be of positive quality (§ 155), and which is probably the base, or part of the base, of the physiologic molecule of the axial fiber, the complete molecule of the axis being chemically electro-negative. The central part of the spermatic filament running its whole length is probably a primitive axis cylinder. Its units are surrounded by protoplasmic elements from which it replenishes its store of energy as the molecules of an axon does from a nerve cell (§ 162), or as an anisotropic molecule does from the isotropic substance.

235. The axis is seemingly exposed at two points, the posterior terminal and the neck; and at one of these points its excitation must take place. It re-

quires an alkaline or electro-positive fluid to excite it because of its negative molecular potential. When excited the axis becomes polarized and the point of excitation becomes negative (§ 188). That is, the unit excited turns its negative pole towards a positive fluid, and its positive pole towards a negative molecular potential in the mass of the axis.

It has been said that the wave commences at the neck and proceeds towards the tail; this indicates that the neck is the point of excitation and leading off point. The head terminal becomes negative and the posterior terminal positive, as shown by the experiment of Mayer (§ 190, § 191).

236. After ejaculation the seminal fluid probably bathes the cervix uteri. What are the forces by which the spermatozoa enter the os uteri, traverse the uterine cavity and Fallopian tubes, and are thus brought in contact with the ovum? It has been stated that the uterus when undergoing the venereal orgasm by suction draws the spermatic fluid within its cavity. This may be an important factor in some cases as far as traversing the cervix is concerned; but there is a large proportion of women that bear children that never had an orgasm; and there are well authenticated cases in which the fluid was merely placed on the vaginal lips. It is evident that suction during an orgasm will not explain these cases. An important consideration in the explanation of the phenomena attending the traversing of the female generative organs by spermatozoa is that the ovum travels by means of stationary cilia and the spermatozoon travels by means of an independent cilium. The evidence shows, however, that although the sperm-cilium by its molecular polarization furnishes the momentum by which the forward

movement is accomplished, the direction of the movement is effected by the terminal potential of the head or neck, which is electro-negative. The tail wags and the head has to move, but the direction of the movement is according to the instinct of the negative head or neck.

The head of a spermatozoon being the negative end, when in the proximity of the os uteri, will be attracted to the os because of the positive potential of the uterine secretion. When within the uterine cavity the chief force that directs the sperm is the ciliary current. The problem for solution is: What way do spermatozoa travel upwards by this current when the ova travel downwards by the same force?

237. Flint refers to a memoir by Lott containing observations on the behavior of spermatozoa under the microscope, and in the presence of electric currents. It was shown by the experiments of Lott that in the part of the field where the current was strong the moving spermatozoa were carried along with it, but when the current was comparatively feeble the spermatozoa made their way against it. In treating of the galvanic current passing through fluid (§ 61, 59) it was stated that oxygen in the molecule of water becoming electrified by the positive current was attracted towards the negative to the point of neutralization, and then by induction it immediately returned to the positive pole.

238. Now, a critical examination will show that the fundamental principles governing Lott's experimental facts and those governing oxygen in a fluid are identical. Oxygen when charged positively will seek the negative pole, but when not charged it will seek the positive pole by induction. In Lott's experiments the spermatozoids when under a strong current become

directly charged, and by virtue of that charge are carried towards the negative pole; but when very small currents were used other materials more minute and more easily moved was charged, and in this case a spermatozoid, being of negative potential at the head and negative in aggregate mass, as oxygen is negative, moves by induction towards the positive pole.

The ova are carried along mechanically by the ciliary movement, which is directed by the potential of their free ends which is of positive quality. The spermatozoa do not touch the cilia, but by induction seek the positive pole of the ciliary current which is at the ovarian end of the Fallopian tube. They are directed entirely by the negative potential of the head; which, like oxygen and other negatives, seeks the positive pole.

Fertilization

239. The spermatozoa and the ovum usually meet in the Fallopian tube near the ovarian end. The spermatozoa approach the ovum and surround it in large numbers. They lash their tails and several may succeed in reaching the perivitelline space, but only one penetrates the substance of the ovum. The success of one causes the collapse of the others. The head of the successful one, now called the sperm-nucleus, separates from the tail and makes its way towards the center of the ovum. By the act of separation the sperm becomes an electro-positive body dominated by the nucleolus. The egg-nucleus also moves towards the center, where the two meet and form the first segmentation-nucleus. The middle piece accompanies the head to the interior of the egg.

What is the character of the attraction that exists between the nuclei or nucleoli of the sperm and the ovum? Admittedly physiologists have not found a satisfactory answer.

We have stated that crystallization, coagulation, contractility, gland-cell action and conductivity depend upon polarization, and we now bring forward this fundamental property of all matter to consider it as the cause of the mutual attraction between the nucleoli of the ovum and the sperm.

Fig. 112.

Stages in the fertilization of the egg (*after Wilson*). The drawings were made from sections of the eggs of the sea-urchin, *Toxopneustes variegatus*, Ag. A. the surface of the egg has become elevated to form C, the entrance-cone for the spermatozoon; the head (H) and the middle piece (M) of the latter have entered the egg. B. Five minutes after entrance of the spermatozoon; the head, now the male pronucleus, has rotated 180 degrees, and has travelled deeper into the ovum; the cytoplasm of the latter has become arranged in a radiate manner about the middle piece of the spermatozoon, now the centrosome, to form the spermaster; the egg-nucleus, now the female pronucleus, is approaching the sperm-nucleus; its chromatin forms an irregular reticulum.

240. It must be distinctly kept in view that neither the nucleolus of the ovum nor the centrosome of the sperm has been called into functional activity previous to their union. The part played by them has been entirely negative. They have been built up from the potential of environing structures (§ 159), but separately neither is capable of performing their special function. That function fundamentally is simply to

alternately polarize and depolarize, and specialization resides in environing conditions. It is seen that certain salts cannot crystallize without the water of crystallization, that coagulation cannot take place without the presence of calcium, and that muscular contraction is only effected in the presence of certain salts in the iso-

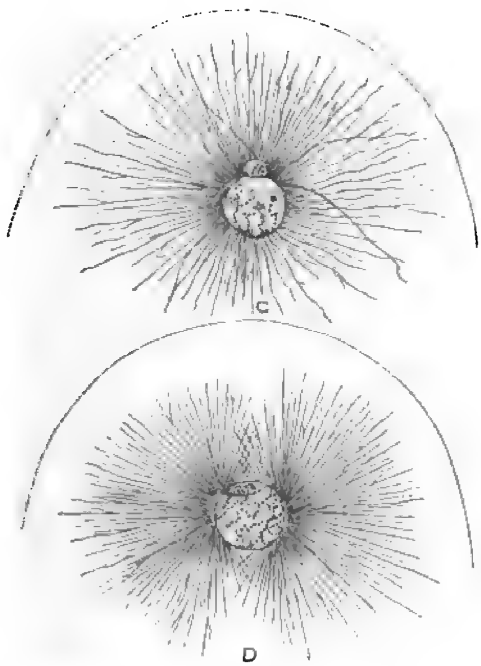


Fig. 113.

Stages in the fertilization of the egg (continued from **Fig.** 112). C. Ten **minutes after entrance** of the spermatozoon; the male and the female pronuclei **have met near** the center of the egg and the fusion has **begun; the former has** become enlarged and its chromatin has become **loosely reticulated**; the sperm-aster has become enormously enlarged; the **single centrosome has been** divided into two, which lie upon either side of the **sperm**-nucleus. D. Still later after entrance of the spermatozoon; the two pronuclei have united to form the first segmentation-nucleus; the sperm-aster has become divided into two asters, **which have moved** to opposite poles of the nucleus; the egg is now **ready to undergo segmentation**. (*From the American Text-Book of Physiology.*)

tropic substance; furthermore, that the common basis of these and other phenomena is polarization, and the essential additional substance we have called *associated molecules of polarization.* In short, the theory is here advanced that the relationship of the sperm centrosome to the germ-nucleolus is identical to the relationship of the associated molecules of polarization to the polarizing body, and to the relationship of the water of crystallization to the crystallizing salt. Clearly an electro-positive element such as calcium existing in the sperm-centrosome is the base of the associating molecules of polarization of the germ-nucleolus, the latter having a potential similar in quality to hydrogen carbonate, which is electro-negative.

241. Observations prove that the germ-nucleus advances to the center of the ovum to meet the sperm-nucleus, and that only one spermatozoon penetrates the ovum. This proves that a distinct spherical equilibrium has been established between one spermatozoon and the ovum and that attraction has ceased. For the first time in the history of the germ-nucleolus it rounds out into a true spherical form under molecular polarization. Under the stimulus of the new conditions it immediately proceeds to divide.

The sperm-nucleus seems to be added grossly to the germ-nucleus, and both are brought under the inductive magnetic influence of new nucleoli or centrosomata.

CHAPTER XIX

Cell-Division

242. An adult cell consists of:

1. The *Nucleolus*, a highly refracting body, differentiated from the other parts of the cell by peculiar staining. It closely approximates but is separated from the nuclear material. It disappears during the division of the nucleus, and reappears within the newly formed nuclei. Chemically it is supposed to consist of paranuclein.

2. The *Nucleus*, surrounding the nucleolus, and surrounded by a nuclear membrane. It contains complex chemical constituents reacting differentially to staining reagents, the most pronounced being chromatin, the interspaces of which is filled by a nuclear matrix, the achromatin substance. Chemically the chromatin has nuclein as a constituent. It presents itself in different forms according to nuclear activity, usually as strands or threads. Within the chromatic substance there has been observed a network of very fine threads, achromatic in character, called the linin.

3. The Protoplasm, enveloping the nucleus. It consists of a highly elastic and extensible portion called the spongioplasm or mitom, and an interstitial substance, the hyaloplasm. The spongioplasm is generally assumed to be fibrillar in character.

Recent investigators have described the paranucleus, which, according to Platner, is an extrusion of the nucleus. It lies within the protoplasm near the nucleus. Also a very small, round, highly refracting body, called the centrosome, has been found in certain cells. The centrosome is surrounded by an area called the attraction-sphere. The paranucleus and the centrosome conspicuously manifest themselves during the changes incident to the division of the nucleus, although they are supposed to exist during cell-rest. The centrosome is considered as the dynamic center of the cell, as it becomes prominent during cell-division. In the resting

Fig. 114.

Structure of the cell as described by observers: A, spongioplasm, arranged as reticulum, hyaloplasm lies within the latter; B, cell-wall; C, chromatin filaments, between which lies nuclear matrix; D, nuclear membrane; E, nucleolus.

cell it has been described as a single or double punctiform body surrounded by a clear area showing fine radiate lines.

The manifestations of structural changes, in the several phases of mitosis as described by observers, are essentially as follows:

Amongst the early mitotic events is the disappearance of the nucleolus. Migration of the centrosome takes place, followed by its division into halves, which move apart. Round each half, or new centrosome, are

developed delicate rays; part of these rays constituting an achromatic spindle of which the two centrosomes are the poles. The material of this spindle is supposed to be identical with that of the linin.

There occurs an increase and rearrangement of the nuclear chromatin, which forms convoluted fibers called skein or spirem. These fibers are known as chromosomes. As the achromatic spindle develops the chromosomes are crowded round the equatorial plate or monaster. In the stage of metakinesis the chromo-

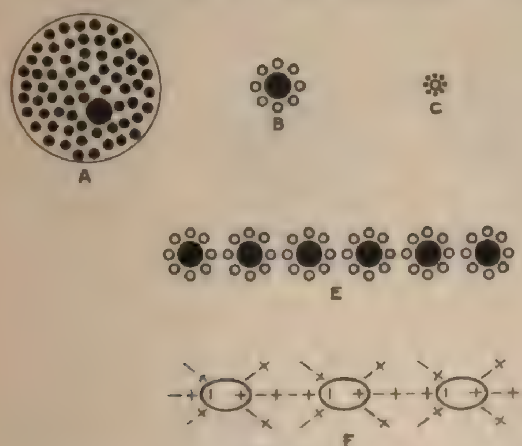


Fig. 115.

Showing constituent units of cells at rest and in action: ●, negative molecules; ○, positive molecules; A, showing nucleolus surrounded by chromosome molecules, each occupying separate spaces, according to the concept of the resting vital nucleus; B, a chromosome molecule surrounded by achromatic positive material, such as nuclein, proteid, hydro-carbon, and alkaline matter, the latter occupying the induced field of the chromosome molecule; C, an achromatic positive molecule surrounded by oxygen molecules, typifying nutritive molecules—proteid, hydro-carbons with oxygen—the oxygen being taken on in the pulmonary circulation, and combustion occurring in the cell; D, oxygen molecules—the intermolecular spaces being occupied by ether; E, representing fibril in the cytoplasm with units at rest and free to assume the globular form; F, representing fibril in cytoplasm with units in action, the plus and minus signs in induced field showing polarized positive matter.

somes undergo *longitudinal cleavage*, each furnishing two daughter chromosomes. The daughter chromosomes derived from an original chromosome separate and each is connected by *traction fibers* with its respective centrosome. As the groups of daughter chromosomes—daughter stars—separate the traction fibers shorten. The separation of the daughter stars proceeds until complete division of the cell-body is effected by a gradual ring-shaped constriction near its center, thus dividing the protoplasm. Towards the termination of the process a skein is formed from the

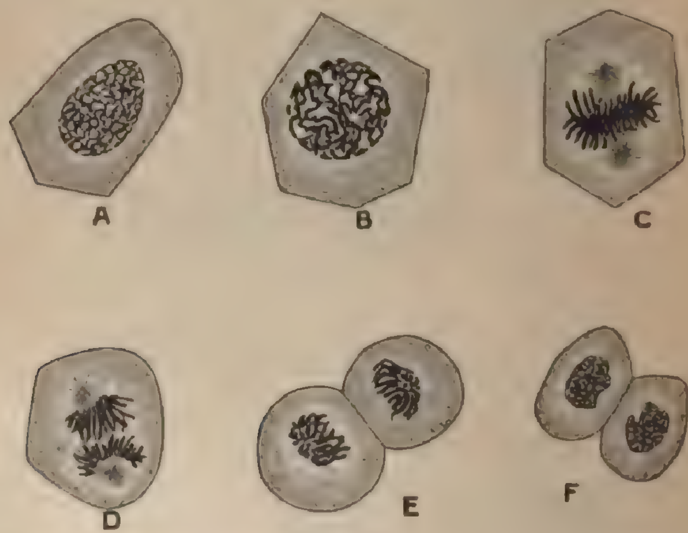


Fig. 116.

Mitosis: A, resting-cell previous to assuming the mitotic condition, showing irregularly contoured threads in nucleus; B, cell at beginning of mitosis, showing chromatin loops called stage of *close skein*; C, showing chromosomes grouped around equator of achromatic spindle, at the poles of which is seen the centrosomes, *Monaster*; D, the chromosomes are divided longitudinally into two groups, which are seen approaching their respective poles, *Metakinesis*; E, completion of cell-division, *Dispirem*, showing constriction dividing cytoplasm; F, resting daughter nuclei, *Telephase*, modified from Sobotta (*translation by Huber*).

chromatin of each daughter star, followed by the completion of daughter nuclei with the acquisition of nucleoli. Thus each daughter cell receives half of the original centrosome, half of each chromosome, and half of the cell-body.

Early in the history of cell-division the nuclear membrane disappears, and is again acquired towards the completion of the process.

243. The chronological order of segmental changes is not exactly agreed upon by observers. We have therefore considered them as they pertain to the histologic elements of the cell, our purpose being to elucidate our conception of the principles involved in the cycle of events which collectively constitute karyokinesis. It is essential that the potential character and relationship of the constituent parts of the cell be understood not only as regards the mitotic, but also as regards the resting condition. It is equally essential to bear in mind the fundamental laws of attraction and repulsion as formulated (§ 1, § 23, Fig. 5) in the physical part of this work.

That the nucleolus is a body molecular in character the author is fully convinced. That its inductive potential is negative is evidenced by its affinity for basic dyes, and by the quality of similar units. Accordingly it will repel all negative bodies and attract all positive bodies, just as an electrically negatively charged body does (§ 23). A differentiation in the chemic constituencies of the sperm centrosome and germ nucleolus should be demonstrable by dyes. If the nucleolus were composed of two or more negative molecules these would mutually repel, and the refracting and other properties would be lost. This repulsion is manifested when a centrosome becomes two molecules by

mitosis. If the centrosome were not molecular it could have no attraction-sphere, as each molecule of a mass has its own induced area. *There is no differentiating line of demarcation in matter, except that between the molecular and the mass conditions, which will explain the intrinsic cohesiveness or concentrativeness of a centrosome-body and the extrinsic diffusibility of daughter centrosomes. The mass of two centrosomes is diffusible, the molecule of one centrosome is concentrative.*

The nuclear area is the induced field of the nucleolus. That is, if the nucleolus is regarded as having a greater inductive potential than neighboring molecular bodies it will have an inductive or disturbing influence over surrounding potentials, and will dominate the latter according to the law of forces. The nuclear area is filled with numerous negative molecules, also chromatic, which may be termed *chromosome molecules*. The nucleolus consequently exercises a repelling influence over all of these molecules; and the chromosome molecules repel each other. Moreover, the mass of the nucleus will repel a similar mass. Each chromosome molecule is surrounded by material of positive and of achromatic character, and this material is attracted towards the nucleolus and towards each chromosome molecule. As the negative molecules repel mutually according to the law of distance (§ 1, § 30, § 101), the distance between them is in direct proportion to their inductive potential, modified by pressure and temperature. The amount of positive material in the cell, that is, in the induced fields of the negative molecules, is therefore specific. In the living cell the negative molecules in the nucleus must remain apart, their inherent potentials being mutually repellent, and being dominated by the potential of the nucleolus, which occupies

the potential or dynamic center. Hence the formation of the chromosome fibers described by observers must result from loss of vitality (of the nucleolus), or from artificial changes produced by manipulation. No doubt the fibers constituting the linin are also artificially formed, the positive molecules of which are dominated by the larger negative molecules. The positive material consists of nuclein, proteids, hydro-carbons, and alkaline salts. The nuclein may become the basic part of the negative molecules, being changed by the metabolism of the cell; the other proteids and hydro-carbons are nutritional, and the salts have a specific relationship to cell function, probably being associating molecules of polarization. An important consideration in this plan of molecular arrangement is that the proteid and hydro-carbon molecules carry oxygen in their induced fields, and are thus potential carriers to the cell. From these is furnished the nutrition of the cell, and the initiation of cell changes must arise from a modification of its nutrition. It must be borne in mind that throughout the processes of cell-division a nutritional stream is pouring into it, upon the character of which depends the character of cell-changes. For instance, a supply of hydro-carbons alone does not suffice for cell reproduction (§ 1, § 300), although it suffices for certain cell-activities. A segmenting cell must be supplied with all the elements—carbon, hydrogen, nitrogen, phosphorus and oxygen—of which it is composed.

The centrosome is the distinctive mitotic figure. Its origin has not been decided by observation. The author's opinion is that the nucleolus and centrosome are identical; although any chromosome or nuclein molecule built up under nutritional strain is capable of assuming centrosomic properties. On the eve of a cell

taking on mitosis its quantitative nutrition must be in excess of its mere maintenance. Every molecule, therefore, must have its potential raised to the highest pitch of equilibration (§ 159, § 162). Hence the nuclear resting equilibrium is disturbed and the potential resting-center changes. Consequently the repulsion between the increased negative potential of the nucleolus and the increased negative potential of the chromosome molecules drive the nucleolus beyond the nuclear circumference. Thus it becomes the centrosome. However, during the period of the cell-rest any negative molecule may be increased in potential and exhibit an induced field similar to that of the centrosome. It is the central position of nuclear forces that is the chief factor in this distinctively anabolic process. The factors in the maintenance of nuclear equilibrium are: nutrition, pressure, temperature, and the differential potentials of the constituent molecules; and a change in any of the factors will signify a disturbance. The nutrition of the mitotic cell is beyond the needs of the maintenance of the resting cell, and the nutritional elements must contain quantitatively and qualitatively the atomic elements of the dividing cell, otherwise a similar cell could not be produced. In this resides the initiatory cause of karoykinesis. The mitotic process is anabolic in character and is effected at the expense of katabolism of the nutritive elements, which is in principle a combustion between the proteids or hydrocarbon molecules and the oxygen in their induced fields, specific pressure and temperature being required for their chemic union. The anabolic process affects the nucleolus, chromosome molecules, and perhaps nuclein; the latter, although positive, may be metabolically related to negative chromosome material. The

repulsion of an increased negative potential forces the nucleolus to change its relative position.

Centrosome, nucleolar, and chromosome molecules have distinctive potential-quality. They are built up by new material being added to their surface until the centrifugal and the centripetal forces balance. Extrinsic pressure and intrinsic centripetal forces support each other in determining the quantitative anabolism; and the character of nutritive association determines it qualitatively. As the molecule is increased in dimensions there is a tendency toward the formation of new centers at its circumference, but this alone is not sufficient to produce the phenomena incident to cell-segmentation.

The conception of molecular polarization has been formulated (§ 154, § 156) and advanced as the fundamental principle of functional activities of muscle, nerve, and gland-units. Moreover, the dissociation of molecules by chemic action, by reduced pressure, or increased temperature, is preceded by molecular polarization (§ 34, § 36); as in each of these cases the dissociated molecules of complex matter do not divide into qualitatively equal groups of atoms, but into a more positive and negative group, this grouping must be accomplished by polarization, although the molecular construction may not favor hemispherical equality. It is a temporary polarization accomplished by extrinsic force.

The principle of molecular polarization will now be considered relatively to cell-division. The elements of molecular polarization have been given as symmetrical hemispheres, and qualitatively differentiated but quantitatively equal polar potentials. An essential requisite to these conditions in molecules of inductive potentials

is the presence of *associating molecules* which become *dissociating* molecules during depolarization. As a corrollary to these essentials we have advanced the conception of *dissociating molecules of polarization* existing under favorable conditions. It follows that an associating molecule must be specific in its dimensions and in the quality and quantity of its potential. If more than one molecule associate, these requirements will apply to the aggregate. Consequently the character of the polarizing molecule determines the character of its polarizing association. Conversely, under highly complex molecular construction with delicate responsive atomic equipoise the character of the presenting associating molecules of polarization may determine the character of the polarizing sphere. Thus the centrosome, built up to a maximum potential, under the influence of slight stimuli polarizes. Like other physiologic units, it requires associating molecules of polarization of specific character, which are furnished by the alkaline salts in the cell. The centrosome polarizes, but like the polarization of all other molecules, whether simple or complex, whether the manifestation be as crystallization or as a physiologic function, its polarization must be preceded by its intrinsic wants and its surrounding conditions being reciprocally responsive and capable of equilibration.

Here let us recall the essential facts of crystallization, the great physical analogue of physiologic action: (1) Specific temperature of the crystallizing and dehydrating points; (2) a specific number of molecules of water of crystallization, or of other substances—associating molecules of crystallization. Thus a molecule of magnesium sulphate requires seven molecules of water in order to equilibrate as a molecular sphere, whereas

magnesium sulphite requires six molecules of water as associating molecules. These salts have specific temperatures at which crystallization and dehydration take place.

The mitotic cell is supplied with nutrition beyond the measure of its requirements during rest, and consequently the centrosome is built up to maximum dimensions and to a maximum negative inductive potential. Its essentials of polarization are the same as its inorganic prototypes, but its character differs from that of the latter in chemic instability, and in the number of atoms in its construction. The requisite essentials of polarization of such a molecule in its entirety not being present, its flexibility allows it to polarize in conformity with those conditions which are present. The temperature of the cell is specifically suitable to the polarization of a portion of the centrosome, and a present salt furnishes the necessary associating molecules of polarization for the same partial quantity. Hence the centrosome polarizes with smaller dimensions extruding a part as a *dissociated molecule of polarization*. The extruded part may also polarize simultaneously with the included part, thus effecting a double polarization; or the extruded part may be built up to greater dimensions and to a higher potential and then polarize. The conversion of saccharose into dextrose and glycogen, followed by the glycogen being built up to levulose is a somewhat similar process (§ 213). After polarization both daughter nucleoli are anabolically changed, by nutritional pressure, to higher potentials, and as they are negative they mutually repel in accordance with the law of distance. Mutual repulsion also exists between the centrosomes and chromosomes.

Within the induced fields of the chromosome molecules there is positive material—the linin. As the centrosomes recede they dispute possession of this material with the chromosomes, and hence the achromatic spindle is formed. Deprived of the material in the induced molecular fields, the chromosomes are crowded around the equator of the achromatic spindle. At this stage the nutrition of the cell is more particularly directed to the chromosomes, the molecules of which are raised in negative potential, consequently each molecule is divided by exactly the same means and in the same manner as division takes place in the centrosome. The halves of each chromosome and of each chromosome molecule repel each other because of their negative potential.

The most interesting portion of the cell at this stage of the mitotic cycle—the stage of metakinesis—is the achromatic spindle, which up to this time has played a passive part. Being positive in the quality of its potential, it binds each group of the chromosomes to its respective centrosome, and as the repulsive force decreases with the square of distance, repulsion and attraction reach a point of equilibration, which is lost as cell-division nears completion. The achromatic material is still being re-enforced by nutritional elements, although combustion has ceased owing to increased resistance due to the negative molecules having reached their anabolic height. The nutrition now influences the cell physically instead of chemically. The attraction of the positive material of the achromatic spindle now becomes active and draws the negative centrosome toward the corresponding group of chromosomes until the centrosome is lost amidst the chromosome molecules. This admixture of positive and

negative material is similar to osmosis and depends upon the fundamental attraction of positives and negatives. The attraction is the same in kind as, but less in intensity than chemic action, and stops when the equilibrium of the cell is regained. The manifestation of delicate balances will be clearly understood when a correct conception of ultimate forces is acquired.

The cell as a whole being negative, the portions dominated by respective centrosomes mutually repel, and thus complete separation takes place through the middle of the cytoplasm. An equilibrium is thus established between the centripetal and centrifugal forces of the cell-body, the whole being dimensionally and potentially related to the character of its component units. Thus just as the interspaces of the negative molecules of the cell are regulated by mutual repulsion, and are in direct proportion to their potentials, so the spaces between the nuclei of cells are regulated by mutual repulsion, and are in direct proportion to their negative potentials, all distances being modified by extrinsic pressure, and all potentials acting according to the law of forces (Fig. 5). Thus, according to this law, two nuclei mutually repel, although the elements of their cytoplasma are sufficiently free to act and react, and respond to extrinsic stimuli. Clearly the nucleolus dominates the nucleus as its induced field, so that to extrinsic stimuli they act as one potential body; and two nucleoli (reinforced by the potentials of their respective nuclei) mutually repel, leaving an interspace in which matter is relatively free. Thus cells may be represented as negative molecules with induced fields and interspaces as shown in Fig 6. There is this difference between cells and the negative molecules of gases. In the induced fields and interspaces of the

molecules of gases there are ether molecules at zero-potential; and in the induced fields and interspaces of nucleoli there are molecules of inductive potentials, which by virtue of their quality have large *specific inductive capacity* (§ 101, § 294).

The disappearance of the nuclear membrane is caused by the dissolving influence of the increased negative potential of the centrosome and chromosomes. It is reformed by material passing beyond their influence, the molecules then rearranging according to their own polar attractions. The events evidence the existence of a varying inductive potential on the part of nuclear constituents.

244. *Maturation of Ovum.* This process has been followed in many of the lower animals, but has not been demonstrated in mammals. The important features are as follows: The nucleus approaches the periphery of the ovum and undergoes karyokinesis. The upper daughter nucleus invested with a small portion of the protoplasm is extruded into the perivitelline space formed by the shrinking of the vitellus. The lower daughter nucleus again segments and the second upper daughter nucleus is likewise extruded. The remaining fourth of the original nucleus, now called the female pronucleus, recedes towards the center of the ovum. The space between the zona pellucida and the vitellus caused by the shrinking of the latter becomes filled with fluid—the perivitelline fluid.

In the maturation of the ovum there is manifested what may be termed mitotic abortion, and its determination has two factors: (1) Decrease of pressure which the ovum undergoes as it escapes from the Graafian vesicle; (2) a remnant of nutritional conditions which existed before the development of the

basement membrane—the theca—of the Graafian vesicle. As in a vacuum tube, where the decrement of pressure separates the molecules of gas into two parts, the one more negative and the other more positive than the original, so the centrosome with its decrement of pressure tends to divide, and the division results in a less negative—possessing more positive constituents, but in its entirety specifically negative (§ 36, § 70)—and a more negative daughter centrosome than the mother centrosome. At the beginning of the development of the Graafian vesicle nutrition is of such a character as to allow mitosis of the follicular cells to take place; after the development of this membrane cell-segmentation is impossible owing to change of nutrition. It is conceivable that a residual amount of the nutrition essential to segmentation, assisted by the decrement of pressure, causes a modified cell-division as that which takes place in maturation of the ovum. A residuum of alkaline salts acts as a stimulus and as associating molecules of polarization, the character of the residuum also assisting in the determination of the dimensions and relative potentials of the daughter centrosomata. As a result of these conditions the extruded nucleoli and nuclear chromosomes have small inductive potentials and consequently carry a small proportion of the cytoplasm. The remaining nucleolus and chromosome molecules, although reduced in size, have increased negative potentials and the whole cell has been brought into equilibrium with surrounding conditions.

Segmentation of a Fertilized Ovum. The male and female pronuclei unite and form the ***segmentation-nucleus***, and the whole cell thus modified is termed the ***blastosphere***. The cleavage of the blastosphere results in two cells of unequal size. One, which may be desig-

nated as the outer, is slightly larger and paler than the other, the inner. Cleavage in the outer occurring more rapidly than in the inner, the outer cells spread over and enclose the inner, so that by the ninth or tenth division there is an external layer of pale cells enclosing a mass of smaller and more opaque cells.

To understand the relationship of male and female nucleoli we must bear in mind the distinctive character of the two bodies. The female nucleolus has been built up under great pressure to a high negative potential—its constituents consist of a very large number of chemic atoms and these preponderantly electro-negative. It is surrounded by negative chromosome molecules constituting its induced field, the nucleus. The chromosome molecules are surrounded by positive material, but it does not, as in mitotic cells, fulfill the nutritive requirements of segmentation, a fact which is undoubtedly sequentially related to the anatomical construction of the Graafian vesicle (§ 228). There is no stimulus to polarization, neither are the associating molecules essential to polarization present. On the other hand, the male nucleolus is electro-positive. Like the female nucleolus, it is surrounded by chromosome molecules of negative quality, and these are again surrounded by electro-positives. However, there is an important difference in the positive nutritive material of the sperm, in that it fulfills the requirements of segmentation, and this no doubt is sequentially related to the structure of the testes.

The female nucleolus, being negative, requires an initiatory *positive stimulus*, *positive associating molecules of polarization*, and *elements capable of modifying nutritional conditions to segmental requirements*, and these the male pronucleus furnishes.

Every molecule polarizes with spherical dimensions determined by its quantitative and qualitative potentials, and by the degrees of temperature and of extrinsic pressure. As pressure decreases molecules tend to decrease in size, but they divide with increased potential. (§ 34, § 36, § 144). The male nucleolus stimulates the female nucleolus just as the sperm axial fiber is stimulated by an alkaline fluid. Consequently the female nucleolus rounds out into a true spherical form with differentiated and equilibrated poles, at the same time it associates molecules of polarization from the sperm nucleolus. However, the high negative potential of the female nucleolus and the lessened pressure compared with that under which it was constructed prevents polarization from embracing the whole body of the female nucleolus, and part of it is excluded from participation in the spherical construction. This portion is the dissociated molecule of polarization. As the stimulation is positive the part of the body polarized is more negative than the extruded part. The extruded part is less negative and smaller in size than the included part, and polarizes under specific conditions as does the other. Both being negative, they repel each other, and the chromosome molecules of the nucleus are divided in like proportions. Division of the cell-mass is directly proportional in dimensions as the divided potentials of the nuclear molecules.

Molecules when dividing under decrement of pressure conform to the following law: *The dimensions of the dissociated molecules are inversely proportional to their constituent positive units and directly proportional to the negative units* (§ 1, § 29, Fig. 118). This law evidently applies to the division of the nucleolus and to the division of the nuclear elements, consequently the dis-

sociated parts consist of a more negative and larger cell, and a less negative—possessing more positive and less negative constituents—and smaller cell, as shown by the first epiblastic and hypoblastic cells. The relative size of the oxygen molecule to that of hydrogen, and the comparatively large negative and small positive molecules in a vacuum tube, show that the law has universal application. The larger and more negative cells surround the smaller or less negative, and this is indicative of another general law as evidenced by an electro-negative atmosphere surrounding an electro-positive earth. The more negative cell is paler, and the less negative is more opaque. These qualities are probably owing to the more negative molecules having greater repulsive force and hence larger interspaces, thus manifesting a tendency to diffusibility and allowing a more free transmission of light. After the first division of the blastosphere, there being no change in the temperature, pressure or nutrition, each molecule polarizes and segments without change of dimensions.

It may be conceived that the male nucleolus has been relegated to a minor position in the fecundating process. This is far from being the case. Each molecule polarizes under distinctive spherical dimensions and demands distinctive additional molecules to round out its hemispheres. But the associating molecules have reciprocal influence and demand that the sphere conforms with the total dimensions and potentials which they can combine to furnish, thus determining the dimensions and potential energy, within certain limits, of the cell. Moreover, it has been shown that the nutritional conditions of the ovum are not suitable for cell-division, and that nutritional influences modify the mitotic results. Hence the influence of the sperm is

exercised through the nutrition furnished to the ovum and through the molecular association which enables the female nucleolus to polarize and divide.

Polarization is an important factor in cell-division; and in a modified form enters into the division of all molecules. In chemism the more positive and the more negative parts form the differential poles of the molecules previous to dissociation, although here the poles are not equipotential. In a vacuum tube the decrement of pressure first polarizes and then dissociates the molecules into more negative and more positive although smaller bodies. Dissociation by chemic action, by decrement of pressure, and by increased temperature is accomplished by extrinsic force and the polarization is not accompanied by symmetrical hemispheres nor equipotential poles; on the other hand, polarization of molecules in crystallization, in blood-coagulation, and in the various functions of physiologic units, is mainly accomplished by intrinsic force and is accompanied by hemispherical symmetry and polar equipotentiality. Mitosis must be added to contractility, conductivity, gland-cell action, electric cell action, blood-coagulation, crystallization, magnetization, and molecular division in general, as being based on the common property of polarization.

The factors essential to the reproduction of a cell are:

1. A cell-unit or molecule having its chemic atoms in delicate equilibrium, and in such relative position that by its intrinsic forces it places additional nutritive elements in similar relative position.

2. Nutritive elements of specific character: (*a*) Elements of the same character as those of the cell

reproduce a like cell. (*b*) Elements of different character modify the character of the cell.

3. Specific degrees of pressure and temperature.

4. A stimulus to polarization, usually an electro-positive element, as the segmenting molecule is usually negative.

5. Associating molecules of polarization of specific potential-value and dimensions.

245. *Cytoplasm.* The cytoplasm is composed of spongioplasm and hyaloplasm. The principle is universal that the active histologic elements of tissues consist of a substance which is comparatively solid imbedded in a substance which is comparatively fluid. What is the difference between the negative material or spongioplasm of the cytoplasm and the negative material or chromatin of the nucleus? We will postulate the fundamental difference as follows: The negative elements in the nucleus are under the inductive influence of the primary potential of the nucleolus; whilst the negative elements of the cytoplasm are free to act according to their own potentials, to more freely arrange themselves according to their polar attractions, to respond individually to extrinsic stimuli, and to functionally differentiate according to environment. The nuclear elements are potentially one body, if they vibrate they move as a whole, they are incapable of conducting a wave motion throughout the nuclear area, and when the nucleus is free, as in the case of a coccus, it is non-motile, although it is sensitive to motory influence as manifested by a to and fro motion (Brownian movement). The molecular elements of the cytoplasm are capable of conducting wave motion because each is a free body and acts independently of the adjoining elements, only that the polarization of one is the stim-

ulus to the polarization of the other. The cytoplasm therefore confers motile properties on the cell, as is evidenced in bacilli, spermatozoa, and leucocytes.

The chromosome molecules passing from the nuclear sphere into the cytoplasmic area become independent or semi-independent bodies. As they have specific negative potentials they have specific distances asunder. These distances are commensurate with the induced areas, which are filled with hyaloplasm. They possess no intrinsic force that would induce a fibrillar formation; but an external stimulus or impulse will pass through them as a motary wave, and according to its direction will force them into lineal extension. It is conceivable that a nervous impulse entering a mass of these highly sensitive, and delicately balanced but irregularly placed units, will polarize and thus cause them to assume a structure of fibrillar character. Thus the basis of nerve conducting structure is formed from potential units brought into symmetrical order by the force which passes through them. Moreover, a fiber may extend itself by the distal or positive pole of the terminal unit attracting another unit, thus bringing it into line. The non-vital fiber as it appears to a microscopist must differ considerably from the vital fiber. In living tissue each physiologic unit must be a distinct body independently performing the fundamental action of polarization, and it must have, as shown in the muscle unit, an induced sphere; on the loss of vitality with a change of temperature and pressure an analogous change to coagulation of the blood must occur in nerve tissue, and consequently the fiber must have lost those conditions which are essential to conductivity. A study of electric conductors and non-conductors will make this clear—a molecule must have

the property of free vibration, otherwise it is neither an electric nor a nerve conductor. It is conclusive that although nerve units within the living cell are arranged in lineal order, the units are potentially independent, having a mutual repulsion dependent on their negativities, and being kept in position by extrinsic pressure. When vital conditions cease the fibril assumes a cohesiveness owing to fixed polarization of the units, as in coagulation.

It is a reasonable conclusion that the more solid negative elements in the cytoplasm are primarily derived from similar elements in the nucleus, being driven from the nuclear area by the repelling influence of the nucleolus and other chromosome molecules. When the formative stage of the cell has passed additional physiologic units are not required. The nucleolus and nucleus, however, in nerve and in some other cells continue to perform a necessary function, as is evidenced by depletion of the nucleus of a nerve cell after functional activity (Fig. 78). The protoplasmic elements which pass from the nuclear area into the cytoplasmic area of the cells therefore must be connected with nutrition. These migratory elements, built up to a high negative potential by means of nucleolar ions or nutritional katabolites, may be potential-carriers which feed the conducting units after they have suffered waste during the period of action. Potential-carriers seem to be essential to the preservation of the equilibrium of the animal economy. Under certain degrees of extrinsic pressure they take on in some instances molecular nutriment, and in other instances ions, of the same potential quality as their own, and either through means of the circulation or osmosis they are transferred to other localities where they un-

load their potentials to functionating units. In some cells, such as those of heart-muscle, the nucleolus and nucleus seem to have lost their functionating power, and in the voluntary muscle they have disappeared. Muscular fibers are consequently entirely fed from extraneous sources, and the striped muscular unit is probably reproduced from units derived from the blood as a nerve fiber is reproduced.

Between the spongioplasm and the chromatin substance there is a difference hardly explainable by the independent potentials of the one and the induced potentials of the other. An additional factor may be found in the reactions taking place between the spongioplasm and nutritional elements of the cell.

The differential method of division of cytoplasm and nucleus by karyokinesis is pronounced. Each nuclear unit divides into two, and division of the nuclear mass follows; whilst the cytoplasmic mass is divided without division of the cytoplasmic unit. It must be considered that in a mitotic cell the cytoplasm is functionally quiescent, that nutrition is pouring into the cell, and in order that the equilibrium of the cell be preserved the katabolites resulting from combustion must act anabolically upon units of highest potential (§ 159, § 162). It is an anabolism such as takes place in the formation of starch (§ 205) or of sugar (§ 260), and is initiated at the dynamic center of the cell, towards which positive nutritive elements are attracted. The division of the molecular units (centrosome and chromosome molecules) is caused by nutrition; on the other hand, division of the mass of the cell is caused by the mutual repulsion of the daughter nuclei, and this is the only kind of division in which the cytoplasm participates. There is, however, an increase of cytoplasmic

elements which consequently must be derived from analogous elements of the nucleus, or from constituents of the blood such as the globulins. The differentiation of cells is chiefly a differentiation of cytoplasm, and is accomplished mainly by: (1) Extrinsic pressure modifying the form and dimensions of the units, notably as in muscle and nerve tissue; (2) the extension of the cytoplasmic fibril by bringing into line an additional unit either from nuclear or blood elements, as in the growth of dendrites and axones. To understand the method of extension of the nerve fibril it must be borne in mind that a high potential takes possession of lower potentials; thus the terminal unit of a nerve fibril will dissolve tissue in front and thus make room for further extension. This power of dissolution is manifested in the disappearance of the nuclear membrane during mitosis, and the migration of leucocytes through tissues.

It must be admitted that as all cells spring from one cell that their units must possess a common fundamental property, and that function must have a common principle. If there is a common principle to all function, then the fundamental conditions essential to functional performance must pertain to all functionating units. The absence of these essentials means functional death to the unit. In other words, the common property must be retained in whatever tissue the unit may be placed, although environment may modify the accompanying essentials. The author advances *polarization* as the common principle of function, and the common property of physiologic units, and an *induced field* and *associating molecules* as essential accompaniments. If this postulation be true, then any unit can be taken as a type, and the fundamental

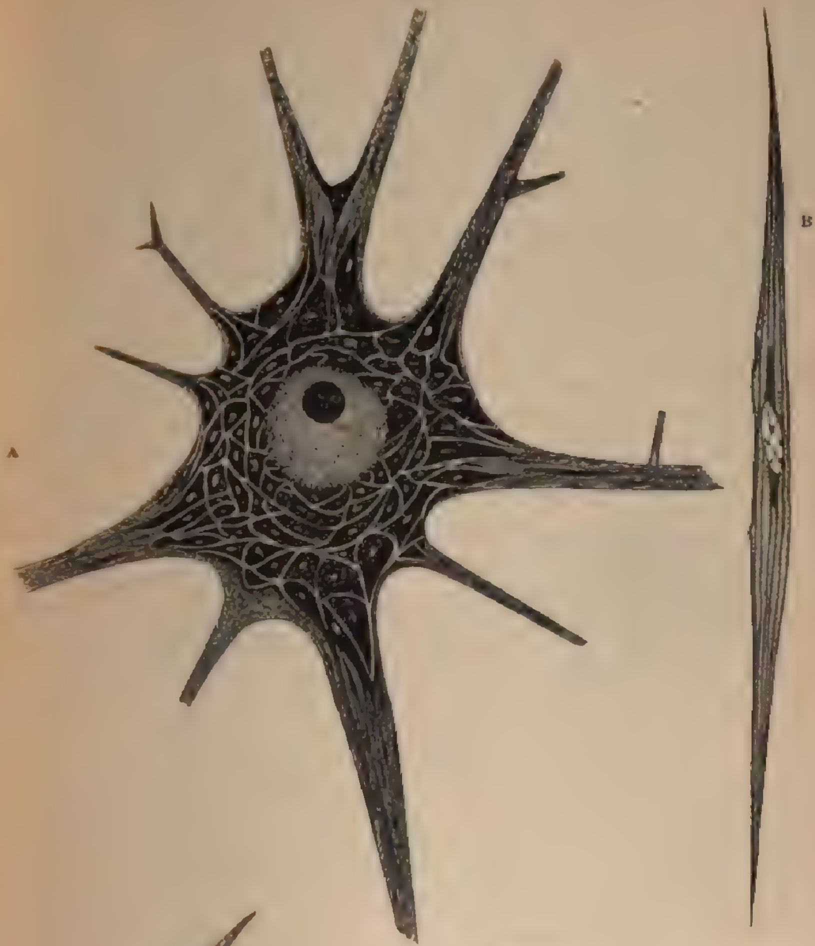


Fig. 117.

Cells differentiated by extrinsic pressure: A, nerve-cell; B, an isolated fiber from the muscular coat of the small intestine (*Schafer*); C, developing voluntary muscle, showing striation. The figures show cells morphologically differentiated by extrinsic pressure, even the nuclei of the muscles being distorted into an elongated form, the distortion being essential to the property of contractility. The nerve is surrounded by structures which insulate and protect without distorting.

conditions obtaining must necessarily be universal. This, however, excepts special conditions which belong to environment. The sarcomere is the physiologic unit (inclusive of its induced field) of the voluntary muscle. It appears conclusive that polarization is the fundamental principle of contractility, and that the evidence is convincing of there being an induced field, and that certain salts are associating molecules of polarization. The sarcomere therefore can be taken as a type of all physiologic units. Consequently there must be a sarcomere in all muscles, and a neuromere in all nerves, although not sufficiently developed dimensionally for microscopical observation. Muscular and neural phenomena support this conclusion. Again, seeing that all units have a common origin and a common property, and that function has a common principle, it would seem probable that there exists, even in adult life, a cycle of changes whereby a unit, or its base, may be transformed from one tissue to another, and thus successively take part in different functions. However it is probable that the constituent elements of units differentiate qualitatively as regards sulphur and phosphorus.

The nucleus, itself consisting of units including the essential nucleolus, is the great elaborator of physiologic units. In certain conditions it evidently becomes inert, or perhaps dies, as in some muscles; in other conditions it retains the property of producing units, as in the nerve cell, and still in others it has the property of reproducing itself in its entirety, as in lymphoid tissues, intestinal glands, and in other tissues during the embryological period. The conception is advanced that nuclein, globulins, etc., in the blood are the basis of exhausted or dissociated units of

leucocytes, that as units they are electro-negative, become neutral by potential waste through amoeboid movements, and ultimately become electro-positive as the cell disintegrates. The electro-positive bodies are attracted by the negative nucleus and nucleolus, and are again built up to negative chromosome units and repelled into the cytoplasm of the cell. If this cell be mitotic it may lift its anchor and become a leucocyte; if it be embryonic the chromosome unit may become a sarcomere, a neuromere, or other unit, and if the tissue

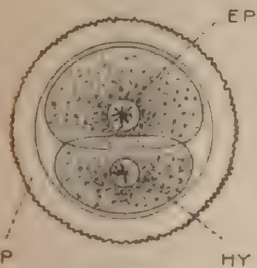


Fig. 118.

Diagram of first stage of segmentation of mammalian ovum, showing division into spheres of unequal dimensions; ZP, zona pellucida; EP, epiblastic cell; HY, hypoblastic cell.

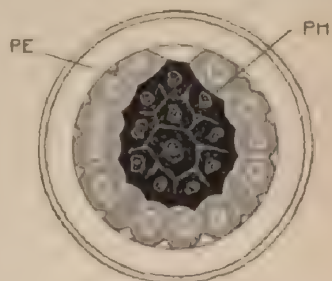


Fig. 119.

Diagrammatic representation of ovum of rabbit at the end of segmentation; PE, primitive epiblast; PH, primitive hypoblast, showing incomplete envelopment of the hypoblast by the epiblast.

to which it is assigned should break down it may be absorbed and become a positive element of the blood. In each of these transformations the unit passes from the blood to the laboratory of the nucleus, and from there to the cytoplasm to become independent. However, it is possible that there is a more direct route between the blood and modified cytoplasm as it exists in nerve or muscle. The question arises: May not unit-bases in the blood pass into fibrillar tracts during

the repair of nerve, or even of muscle, and lay the foundation of units, being then built up to negative potentials by the nutrition of the part?

CHAPTER XX

The Influence of Electricity on Nutritive Processes

246. A correct conception of the important influence of the nerves on gland-cell action, on the circulation, on metabolism and on excretory processes, will make it obvious that electricity through the nervous system, if not more directly, is a powerful agent in aiding the nutrition of the body. Further, when it is considered that chemic action, taking place in all parts of the body, may be transformed into electric currents or potentials, which through their direct or inductive influence produce osmotic action, causing an alkaline reaction to appear at one surface and an acid reaction at another, and that these currents have electrolytic and cataphoretic local influences, it will be readily conceded that electric force is a factor of first importance in vital activity, and that electric applications have a powerful influence over nutritive and other physiologic processes.

247. The mechanical effects of the faradic current by acting on the muscular system, and thus affording passive exercise and massage, and by its acting reflexly on the nerve centers, and sweeping katabolites into the excretory streams, has a positively beneficial influence on nutrition. This is particularly the case in general

faradization with high tension currents of great frequency.

The electrolytic and cataphoretic actions of the galvanic current favor molecular transference from congested portions of the system, and bring to the anæmic parts that activity of cell action essential to physiologic metamorphosis.

Applications of static electricity by embracing within their sphere of action the whole nervous system, influence all the metabolic processes over which the nerves dominate. The most pronounced evidence of the general influence of electricity on nutrition will be found in the treatment of neurasthenic conditions (§ 290, § 311), when, owing to the weakened nerve action, pathologic secretions and various katabolites accumulate in the tissues, and interfere with healthy anabolism, and when through an exhausted nervous system imperfect function results.

248. Electrolytic laws apply equally to organic substances as to inorganic, the differential results depend on the physical and chemic conditions of the organic molecule of high potential, and to the degree of fluidity of the tissues. Therefore if the constitution of the electrolyte-molecule be known it is easy to determine the electrolytic results.

The cataphoretic action of the current is favored the more the chemic stability of the molecule is able to resist electrolysis. Whether electrolysis or cataphoresis takes place depends on the quantitative and qualitative potential of the molecule acted upon, and also upon the physical conditions, solidity favoring electrolysis and fluidity favoring cataphoresis. When a certain degree of molecular stability and solidity are

attained, the current is transmitted by molecular vibration and without electrolysis or cataphoresis.

The action of the galvanic current on the blood has already been studied, and no doubt electric action on all the tissues is fundamentally the same. If a piece of beef be subjected to galvanic action by piercing it with needles connected with the positive and negative poles respectively, it will be seen that bubbles of hydrogen will appear at the negative with a hissing sound. Heat is also developed and can be felt by placing the finger over the part acted upon. It is found that oxygen, acids and other electro-negative elements, including movable cells, accumulate at the positive pole, and alkaline and other electro-positive elements, including coloring matter, proteids and hydro-carbons, accumulate at the negative pole. The electrolytic action, once started, continues for some time after the current is withdrawn. On withdrawing the negative needle it is found that no resistance is offered, and the needle remains bright as when inserted; on the other hand, the needle at the positive pole is found adhering to the meat and is corroded if composed of oxidizable material.

According to Legros and Onimus, if an alkali, as sodium carbonate, is placed at the positive pole, and an acid, as tartaric, at the negative, the corrosion of the tissues is in part prevented. The substances will undergo electrolysis and be diffused, thus neutralizing the ions in the concentrated polar areas.

The faradic current is not used for its electrolytic action, nevertheless it has electrolytic power according to its energy. However, the rule must be adhered to, that whenever electrolysis is indicated the galvanic is the current to be selected owing to its continuous char-

acter. The faradic current, strongly applied, may be capable of breaking up a molecule of high potential and thus producing ions. These ions will not appear at the poles owing to the break in the current. At the same time the molecule may not be reconstructed.

249. Physiologically the action of organs may be increased, diminished or entirely arrested by the effects of electricity. Electric applications generally result in an increased flow of blood; consequently an increase of metabolism and a rise of temperature. Coincidentally the veins are found to be dilated. These facts can be demonstrated by faradization of the feet when cold, these extremities becoming perceptibly warmer during the sitting.

In general the use of electricity increases the functions of secretion and excretion, but under certain conditions they may be decreased. Metallic electrodes placed in the nasal passages increase the secretion of the Schneiderian membrane. Excitation of the chorda tympani nerve increases the secretion of the salivary glands. This may be done by galvanization or faradization of the tragus of the ear. Applications to any part of the face may cause an increase of the secretion in sensitive persons.

External application to the stomach increases the gastric secretion. Electric applications, both local and general, diminish the secretion of the urine in diabetes insipidus and in diabetes mellitus. The menstrual secretion both in physiologic and pathologic cases is affected by electric currents; galvanic and faradic currents, used externally and internally, generally or locally applied, affect the quantity of the menstrual flow. The duration of the menses is also modified. The mammary secretion is also affected by the currents.

Applications made directly to the testicles, or to the perineum, and the spine will increase the secretion of the spermatic fluid.

The action of absorbents is stimulated by electric currents. This action of electricity is best exhibited in morbid growths, as fibroid tumors, hypertrophies, effusions such as hydroceles, pleuritic effusions, or enlarged glands.

Static electricity as a regulator of functions is not surpassed by any other remedial agent. It tends to bring the circulation, respiration, secretion and excretion, and irritability of the nerves towards a normal condition. Metabolism is increased and the absorbents are stimulated. More oxygen is taken into the circucation and the ability to sleep is improved. It is a useful massage through the use of sparks. Static electricity may be used as a counter irritant, as a stimulant or as a sedative at the will of the operator. It excites the specialized neurone to functional activity, and stimulates all organic cells to physiologic action by setting free their inherent potential. It promotes nutrition both local and general; and has marked circulatory effects through its action on the vaso-motor nervous system. By its action on metabolism and its influence on the absorption of oxygen it produces a feeling of refreshment.

CHAPTER XXI

Action of Electricity on Individual Tissues

250. In the study of the action of electricity on the tissues we have to consider the kind of current used, the dosage—strong, medium, or weak—the length of the seance, the polarity of the active pole, and the size, material, and moist condition of the electrodes. In the case of the faradic, the tension of the current and frequency of its interruptions modify the effect.

In addition there is to be weighed the idiosyncrasy of the patient, and the sensitiveness of the organ, its anatomical position, and relative electric resistance. A factor of the utmost importance in its practical therapeutical bearings is the difference in the impressibility of organs in a pathological state from the impressibility of those in a state of health. This particularly is a matter which concerns dosage, and will be dealt with when considering that part of the subject.

Action of Electricity on Skin

251. *Static Electricity.* Sparks produce a sensation of prickling, redness and a papular eruption appearing when they are intense. On the scalp the hair is raised on application of the static spray.

252. *Faradic Current.* The action differs according to the method of application, and kind and intensity of

current. With a dry electrode, at first there may be anæmia, but soon this is followed by hyperæmia. There may be also pain from irritation of sensory nerves. The current of tension rapidly interrupted has more effect on the skin than the current of quantity slowly interrupted. The cause of this is the large resistance offered by the skin. The negative pole has a stronger influence over sensory and motor nerves than the positive.

Some parts of the cutaneous surface are more sensitive to the current than others; this is owing to the unequal distribution of nerves. The forehead, the region of the tibia and scapula, and parts where bones lie near the surface are particularly sensitive. Application by a metallic brush or by a wet sponge lightly made may produce irritation and pain. In some persons the phenomena of "goose flesh" appears on faradization of the skin.

253. *Galvanic Current.* At both poles the galvanic current produces a burning sensation, like that of mustard plaster, varying with the strength of current and duration of application. At the negative pole the action is more intense than at the positive. Delicate skins are more sensitive to the current than coarse skins.

The *chemic* polar effects of the galvanic current on the skin differ. With metallic electrodes slightly moistened there appear at the negative pole small pale vesicles with *alkaline* fluid. Increase of currents will cause blisters, and even ulcers. These take some time to heal. At the positive pole there is first, ichœmia, "goose flesh." This may be followed by a blister with *acid* secretion. A metallic electrode becomes oxidized.

Pain is caused by too great or too concentrated a current. The concentration depends on the size of the electrode and its condition as to moisture and adaptability to the surface. When the skin is more or less dry the electric currents seek entrance at the glands, hair follicles and sweat pores of the skin. Moisture, especially a saline solution, softens the epidermis, decreases the cutaneous resistance to the current, diffuses it by multiplying its points of entrance, thus diminishing its density. Firm pressure against the skin also tends to lessen the pain.

The objective symptoms appear in the following order at both poles: Pallor, cutis anserina, hyperemia, papular projections of the hair follicles, and confluence of papules forming wheals. When the current is strong or long in duration the electrolytic action becomes more evident, and the polar regions differ in chemical reactions.

The anode is less intense than the cathode and the fluid in the wheal is acid. The cathodal area soon presents a blister, and the vesicular fluid is alkaline. A prolonged strong current will cause sloughing.

Cutaneous Anæsthesia. Electric currents produce a slight anæsthetic effect. Induced currents of very rapid vibration benumb the parts to which they are applied. The physiologic unit is incapable of vibrating beyond a certain frequency, hence in high frequencies there is no physiologic response, just as the galvanometer is incapable of measuring the faradic current.

Action of Electricity on the Brain

254. *Direct Application.* Electric currents directly applied to the brain prove that there are certain cen-

ters that control the movements of various parts on the opposite side of the body. Experiments show that the surface of the brain is electrically excitable.

255. *External Application.* When the galvanic current is applied by the longitudinal method—one electrode on the forehead and the other on the occiput—there is slight if any tendency to vertigo. This is also the case where one electrode is placed on the summit and the other indifferently on the body. On applying the current transversely—from temple to temple or from mastoid to mastoid—dizziness is felt, continuing during the application and accentuated at the moment of opening the circuit. There is a tendency to lean toward the positive pole during the passage of the current, objects appearing to move in the same direction. On opening the circuit the reverse order of movement and seeming movements occur. Hitzig enumerates several degrees of giddiness produced by galvanic applications. There may be a mere fullness of the head. This is accompanied by movements when stronger currents are applied; still stronger currents produce staggering. Movements of the eyeballs have been observed to accompany the other phenomena.

Hitzig advanced the following theory to account for the differential action of the galvanic current in transverse and longitudinal applications: When similar centers of the right and left lobes are under anelectrotonus or are under catelectrotonus, as they are in longitudinal applications, they are equally and symmetrically influenced by the current. When the current is used transversely centers of similar function in the right and left lobes are affected unequally, one being under anelectrotonus and the other under catelectrotonus. In the latter case there is a disturbance in the

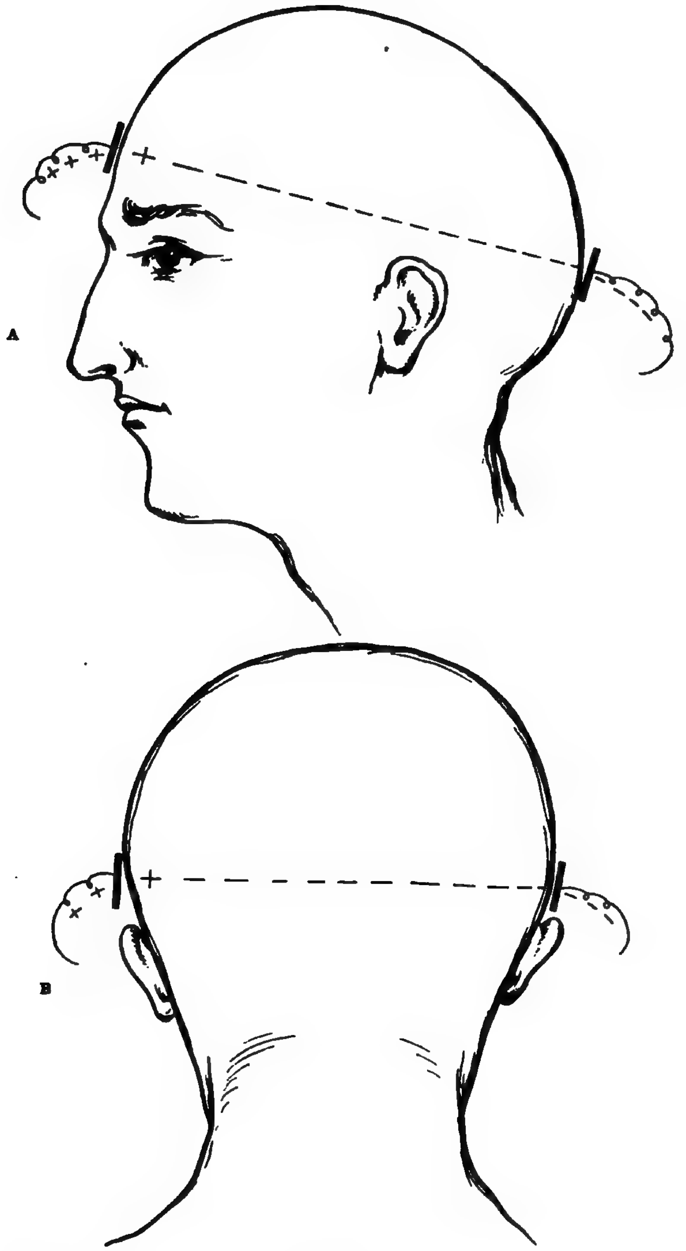


Fig. 120.

A, longitudinal application of galvanic current to brain ; B, transverse application of galvanic current to brain.

equilibrium of centers of lobes of identical function which prevents normal co-ordination. The author accepts this theory with a slight modification. The brain is excited entirely by the negative current (Fig. 102). At the cathode the current is concentrated, at the anode it is diffused. Hence the disturbance of the equilibrium is produced by the unequal stimulation by the current from the cathode.

Action of Electricity on the Spinal Cord

256. *Direct Application.* Contractions of the muscles of the trunk and extremities are produced by applying an electrode to either extremity of the cord, or by placing one electrode to the anterior and the other to the posterior column. If the spinal cord be divided at the center, application of the current to the lower half will produce contraction of the muscles of the lower extremities, whilst application to the upper half will produce contraction of the upper extremities. Either galvanic or faradic applications will produce these effects.

Cilio-spinal Center. This center is between the seventh cervical and sixth dorsal vertebræ, and gives rise to the cervical sympathetic which excites the iris. Stimulation of this region produces dilatation of the pupil.

Genito-Spinal Center. This is near the fifth lumbar vertebra, and its electric excitation produces contraction of the rectum and bladder.

External applications with medium currents will demonstrate the functions of these centers.

Continued applications of the galvanic current to the spinal cord produce a paralyzing effect during the

passage, although contractions are effected when the current is modified. The inhibition is probably similar in principle to negative variation—that is a center under the influence of a force has its potential forces also under control.

Action of Electricity on Nerves of Special Sense

257. *Optic Nerve.* Application of the galvanic current to the optic nerve causes polarization of the neurone with perceptions of light, within the limit of its physiologic vibratile frequencies. The strength of the current, the character of the active pole, the suddenness of interruptions, and the temperament of the subject are found to modify the effects. The faradic current—long coils with rapid vibration—produce light phenomena when applied to the eye, in a beautiful and characteristic degree, distinctive of the coil. The ordinary faradic machines will produce little or no perceptible effect. In experimenting on the eye a soft sponge is placed firmly on the closed lid for the active electrode, whilst the other is applied to the back of the neck.

The experiments are valuable in showing that distinctive physiologic vibrations are properties of nerves of special sense, and indicate that the power of differentiating vibratory frequencies is an inherent property of highly specialized neurones. Each molecule or each cell has its normal range of vibratory action depending upon its quantitative and qualitative potentials (§ 269).

258. *Auditory Nerve.* Ringing, humming, hissing, whistling, or a rumbling sound results from polarization of the auditory neurones by electric applications. The faradic or galvanic currents may be used in these experimentations. The strength of the galvanic current

may be from one to ten milliamperes. Applications to the ear may be made by filling the external auditory canal with water and firmly pressing one pole on the tragus, the other being placed indifferently.

259. *Olfactory Nerve.* The sense of smell can be perceived on stimulating the olfactory neurones by electric currents.

Gustatory Nerve. If a piece of zinc be applied to the upper, and a piece of silver to the lower surface of the tongue, an acid taste will be perceptible under the zinc plate and an alkaline taste under the silver. This arrangement creates an electric cell with a potential resident in the organic molecule.

The peculiar reaction produced by electric applications to the gustatory nerve is generally described by patients as "metallic," "coppery," etc. The characteristic taste is produced in closing the circuit, remains during the application, and sometimes continues for hours afterwards.

The sensation of taste produced by electric stimulation of the gustatory nerve is caused by the distinctive frequencies of vibration of this specialized nerve.

ACTION OF ELECTRICITY ON SYMPATHETIC NERVES

260. In 1832 Claude Bernard demonstrated that following division of the sympathetic nerve there is flattening of the cornea, contraction of the pupil, retraction of the eyeball and congestion of the conjunctiva, with a rise of temperature. Electric stimulation of the cephalic end of the severed nerve caused these phenomena to disappear. Brown-Sequard's experiments on animals demonstrated that division of the cervical sympathetic produced, after a lapse of a few months, partial

atrophy of the brain on the same side, the atrophy no doubt depending on the modification of the intracranial blood pressure.

Direct stimulation of the sympathetic plexus of the abdominal cavity excites the bladder, ureters, uterus and seminal vesicles. Irritation of the splanchnic nerve arrests intestinal peristalsis; on the other hand excitation of the thoracic and abdominal sympathetic promotes peristaltic action.

Sympathetic vaso-motor action has a quantitative relation to secretory processes. Qualitatively secretion is influenced by cerebro-spinal efferent fibers or by local ganglia (§ 208, § 209). Extirpation of the solar plexus produces hyperemia, hemorrhage and ulceration of the stomach; electric stimulation modifies these effects. Intestinal nutrition, peristalsis and secretion are influenced by the abdominal sympathetic plexuses. Puncture of the floor of the fourth ventricle, division of the vaso-motor nerves of the liver, or removal of the cervical ganglia of the sympathetic will produce sugar in the urine. The diabetic symptoms, resulting from paralyzing the sympathetic, are probably accomplished by producing congestion of the liver, thus interfering with its function in converting dextrose into glycogen. The liver also possesses the function of converting glycogen into dextrose, which must be accomplished by means of the action of cerebro-spinal nerves (§ 208, § 209, § 159) on the gland-cells, oxygen and hydrogen ions being impressed into the glycogen-molecule. The reaction is as follows:

$$C_6 H_{10}O_5 + H_2O = C_6 H_{12}O_6$$

Obviously when the circulation of the liver is disturbed and little or no glycogen stored, glucose will be

eliminated by the kidneys. The paralysis of central efferent fibers to the liver will prevent the function of turning glucose into glycogen and prevent an important storage of energy. The diabetes therefore depends upon the sugar of the blood not being converted into glycogen, and the cause is hepatic congestion arising from vaso-motor paralysis. When the normal amount of glycogen is stored in the liver, diabetes may be caused by over stimulation of cerebro-spinal nerves, thus supplying the blood with glucose, beyond the measure of consumption, within certain periods.

Stimulation or paralysis of the sympathetic influences the functions of the kidneys, spleen and the entire genital apparatus.

CHAPTER XXII

Action of Electricity on Pneumogastric Nerve (Inhibition)

261. According to experiments by M. M. Arloing and Tripier faradization of the distal end of a divided pneumogastric causes arrest of the action of the heart, or irregularities of rhythm. They showed that the right pneumogastric has more inhibitory power over the heart than the left. Masoin of Belgium found when the heart movements were stopped by galvanization of the right pneumogastric it was not possible to restore them. The heart's action, however, was capable of being restored after being stopped by galvanization of the left pneumogastric. It was found by Brown-Sequard that electric stimulation of the laryngeal nerves causes arrest of the respiratory movements.

In 1845 E. H. and E. Weber announced that stimulation of the vagi, or the parts of the brain where they arise, slows or arrests the action of the heart. The part of the brain when stimulated, that inhibits the action of the heart, was located in the medulla oblongata. The effect of stimulating the vagus is not immediate, there existing a latent period extending over one beat, and sometimes two, according to the moment of stimulation. A vagus excitation not sufficient to arrest the heart will lengthen the diastolic and perhaps the systolic period. The force of the contraction is dimin-

ished, the volume of blood in the ventricle at the close of the diastole is increased, but there is also an increase of the volume in the ventricle at the close of the systole, or of the volume of residual blood. The out-put and in-put of the ventricle are both diminished by vagus excitation. According to Franck the walls of the empty ventricle become softer when the vagus is stimulated.

Stimulation of intracardiac nerves by chemical agents causes various reflex actions, such as movements of the limbs. When the vagi are cut these movements do not take place, showing that the afferent action belongs to this nerve. Stimulation of the central end of a cut vagus will act on the heart through the intact vagus, showing that the vagi are centrally reflexly connected.

262. Experiments have shown that a strip of muscle cut from the apex of the ventricle of a tortoise and suspended in a moist chamber will beat apparently of its own accord. A strip of muscle cut into pieces and placed on moistened glass slides will contract rhythmically. These contractions evidently occur without the intervention of nerve fibers. If the tip of the ventricle of a dog's heart, which contains no nerve cells, be removed and warm defibrinated blood supplied to it through a canula tied into its nutrient artery, rhythmic spontaneous contractions will be obtained. It has been found that sodium, calcium and potassium salts must exist in definite proportions in the blood in order to have rhythmic contractions.

Upon stimulating the peripheral end of the severed pneumogastric Gaskel found a positive variation of the muscle current in the heart of the tortoise and crocodile; on the other hand stimulation of the accelerator nerves caused a negative variation. The same experimenter showed that anabolic processes were in excess

during inhibition of the heart-muscle, as exhibited by increase of strength of contraction after cessation of inhibition.

Physiologists are inclined to believe that the inhibitory function of nerves is general and may be found in gland and muscle-action. Bonbuoff and Haidenhim showed that, under certain conditions, stimulation of the cortical area will cause relaxation under tonic contraction.

263. If there exist in the cardiac muscle a physiologic unit or sarcomere—a molecule of high negative potential surrounded by an induced field—it will be readily seen that the smallest particle of muscular tissue is subject to extrinsic excitation, just as the initiatory unit of such a particle is subject to excitation by propagation when in the muscle substance; in fact, each unit is capable of polarizing independently, although contractility is modified by the absence of extrinsic pressure, hence a portion of the muscle contracts without nerve stimulus.

The following explanation is given of the rhythm of muscular contractions. When a physiologic unit is sensitive to stimuli it must possess certain potentials. These are weakened by functional action and by consequent waste. Thus before the unit is again normally sensitive the field must be cleared of waste-elements and the potential regained through the combustion of nutritional molecules. The accomplishment of these processes occupies a definite length of time, which constitutes the rhythmic period. This explanation applies to any group of nerve or muscle units, and it may apply to respiratory rhythm. The rhythmic contractions of the heart require special explanation.

The afferent nerves of the heart no doubt end in contact with the endothelial cells of the cardiac lining. They are traced by anatomists to the substance of the heart. The relationship of an efferent nerve to a muscle or gland is such that an impulse passes along the nerve through the teledendrion to the terminal organ. The relationship of endothelial cells to sensory or afferent nerves must be equally intimate and corelated; an afferent impulse may be said to originate in these cells and conveyed to nerve terminals, the common principle of all functional action being polarization of the unit. Thus the endothelial cells are the true terminals of the afferent fibers of the cardiac pneumogastric. As these cells at rest are electro-negative, and as the leading off points of all waves are negative, natural stimuli are positive. A positive stimulus is present in the serum of the blood, and the initiatory conducting unit, whether in the endocardium or in the nerve proper, polarizes with its negative pole toward the alkaline blood-plasma, and its positive pole toward the negative mass of nerve structure. The impulse is conducted by the afferent fibers to local and cerebral centers, thence by efferent fibers to the cardiac muscle, where it consummates in systolic action. During systole initiatory nerve stimulation is impossible owing to the physical effect of muscular contraction on the endocardium, and during the first part of diastole it is impossible, as the blood does not press on the endocardium. It is during the diastolic height and ventricular fullness, when the blood pressure is greatest on the endocardium, when the cells of the latter are somewhat attenuated, and when each cell is bathed with blood plasma, that the stimulus initiates the polarization-wave. We see then that the initiatory stimulus is

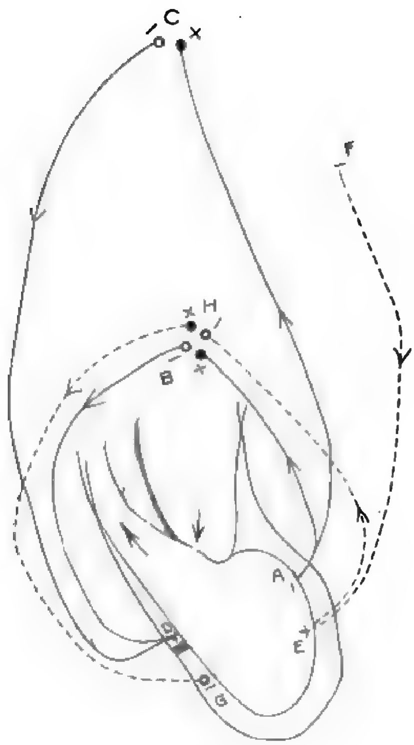


Fig. 121.

Diagram showing nervous mechanism of heart. The symbols ● and O signify positive and negative qualities, or plus and minus, and the arrows show the directions of the waves: A, endocardiac nerve terminal shown as negative during normal polarization, stimulated by positive blood serum; B, intracardiac nerve center, showing positive afferent terminal and negative efferent terminal; C, nerve center in Medulla, showing positive afferent terminal and negative efferent terminals; D, cardiac muscle and positive nerve terminal; E, endocardiac nerve terminal shown as positive, as fiber is stimulated from the cut pneumogastric; F, cut pneumogastric, showing negative leading off point; G, muscle terminal of intracardiac nerve fiber shown as negative, as endocardiac leading off point is positive; H, the same center as B, but reversely stimulated. For the purpose of more clearly showing the reactions the intracardiac nerve centers are not placed within the structure of the heart, and the muscular terminals of nerves are shown on one side, and the endocardiac terminals on the opposite side of the diagram.

synchronous with the end of the diastolic period, and is followed by an impulse through the cardiac nerve-system, with systolic summation, and that the cycle ends in diastole. Under normal conditions the commencement of the rhythmic period is chronologically constant, but in other conditions, such as that produced by a rise of temperature, the diastolic phase may be shortened by the stimulation taking place under less pressure.

When the cardiac muscle-unit polarizes or contracts it requires *associating molecules of polarization* (§ 156), which must be of positive potential, such as calcium, sodium or potassium salts (§ 20, § 184). Hence the necessity of the presence of these in the blood. They reach the muscle through the nutrient artery of the heart.

264. What is the nature of inhibition as manifested by stimulation of the pneumogastric? Merely the sending of an *efferent impulse along an afferent nerve*, which takes possession of the normal impulse-path as follows: (1) It polarizes reversely the conducting cells of the endocardium, thus shutting off initiatory normal stimuli, and (2) it possesses the intracardiac ganglia or neurones by reverse stimuli, polarizing these with their positive poles facing the direction of the normal impulse. The pathways by which normal excitations are carried towards the heart-muscle are thus blocked (Fig. 121). During normal heart-action the intracardial nerves are stimulated from an electro-negative endocardiac surface. The endocardiac surface during stimulation of the vagus is positive, as the stimulated point is negative. It follows that intracardial nerve-fibers have a reversed polarization. Under a strong electric stimulus of the pneumogastric the endocardium

is powerfully electro-positive, thus resisting blood-stimulation, which is also positive. The fact that after a stimulus has been imparted to the pneumogastric one or perhaps two contractions occur before inhibition takes place proves that the point of interception is not at the muscle-cells, but at some distance from them. An excitation wave that has left the endocardium is not intercepted, and consequently reaches the muscle after the vagus is excited.

When a muscle is stimulated its contraction-response accords in degree to the stimulus; although the potential of the muscle-unit is the essential element of force. There is absolutely no physiologic reason for having another stimulus of a different character to modify the first stimulus, as the first can be modified directly. In the usual routine of rhythmic or other muscle-contractions there is no need of, and no such action as inhibition, and no need of inhibitory nerves. However, in a complex system, as that of the human body, nature foresees that something is apt to go wrong, and she provides for an inhibitory and even a positive reverse action, such as in vomiting, but no special apparatus has been found necessary through which to accomplish the inhibitory act.

265. Any terminal strongly stimulated—polarized to a high degree of tension—will take possession, through its induced field, of proximate terminals, and thus inhibit the function of the latter. Moreover, as a nerve trunk is capable of carrying impulses in both directions, as is shown by vagus-stimulation in the arrest of the heart, or by experimentation on nerve trunks (§ 201), inhibition may be defined as an *efferent action in an afferent nerve*. A slight artificial stimulus of the pneumogastric is overcome by the natural excitation,

but the latter may be delayed, consequently diastole is lengthened; a weak artificial stimulus is stopped at the endocardium by the opposing force of the blood stimulus. Lengthened diastole allows a longer period for cardiac nutrition, hence a more vigorous systolic action; if, however, the artificial stimulus of the pneumogastric reaches the muscle through a portion of the intracardiac nerve fibers, then it will oppose contraction and weaken or arrest systole.

Inhibition through the intact nerve by stimulation of the central end of a cut pneumogastric implies that the central terminals of the cut pneumogastric have increased induced fields which influence directly the central terminals of the intact nerve. Although the cardiac accelerator fibers are thus stimulated, the reversed pneumogastric stimulus takes possession of the endocardiac field and inhibits further initiatory blood-stimuli, and at the same time dominates the local ganglia.

266. *Inhibition of the Respiratory Movements.* It has been shown that stimulation of the upper and lower laryngeal nerves causes arrest of the respiration. The principles are the same as in cardiac inhibition, and are referred to under chloroform vibration (§ 279).

The double cycle of vibratory impulses which constitutes the most important feature of the functions of respiration and circulation has its leading off points at the afferent terminals of the pneumogastric nerve. The essential exciting factor is the electro-positivity residing in the alkalinity of the blood (§ 234), although a certain degree of circulatory pressure is apparently necessary. The vibratory waves pass along the afferent fibers of the vagi, and are reflected through the efferent accelerating fibers to the respiratory and cardiac mus-

cular apparatus, thus mechanically influencing the circulation of the blood and affording fresh stimuli to initiatory neural polarization. The local nerves of the heart afford a shorter pathway for the waves to travel than the route through the medulla. As the time in which the waves travel from their starting to their summation points must be exactly equal throughout their distinctive routes, it follows that the shorter or local routes must have slower vibrations than their co-operating larger ones. The difference between the vibratory movements of the longer and shorter nerve fibers may be similar to the difference of movements of voluntary and involuntary muscle fibers as manifested under electric stimuli (§ 268). The intracardiac nerves belong to the sympathetic system the neuromeres of which, like the sarcomeres of the involuntary muscles, may have relatively slow vibrations and tardy responses. The difference of vibration of molecules is manifested in colors, and in electric conduction as shown by the varied resistances of materials (§ 268).

267. *External Electric Application to the Pneumogastric and Cervical Sympathetic.* It has been proved by experiments that application to the cervical region will influence the pulse, and produce a feeling of warmth. Sometimes there is a feeling of drowsiness, which may occur during the seance or afterwards. The effect produced is a resultant of electric stimulation of the vagus and sympathetic.

Action of Electricity on Involuntary Muscles

268. When it is remembered that electricity stimulates all organs and tissues to an increase of their natural functions, the result of its application to unstriped

muscular fiber can be understood. The responses to electrical applications are not immediate as in the case of striped muscles, but a short period of time elapses before contraction takes place, and the contraction remains for some time after the current stops or is withdrawn. It is a tonic contraction resembling voluntary muscular tetanus. Rockwell claims priority in the discovery that the positive pole produces more powerful contraction than the negative on involuntary muscle.

Electric stimulation of a nerve supplying an involuntary muscle produces contraction as in the case of voluntary muscles. The unstriped muscular fibers of the blood vessels, stomach, intestines, bladder, uterus, spleen, gall bladder, as well as of the iris, ureters, vas deferens, tunico vaginalis, epididymis and œsophagus respond to direct electrical applications, but their action is modified by their structure and local conditions and the amount of muscular tissue in them. Direct application of the current varies in results according to the current-strength. Strong currents will arrest the heart's action in a dying animal, but action will return when the current is broken. Weak currents will prompt the heart to act after it has been stopped by a strong current. The difference of action of voluntary and involuntary muscle under electrical stimulation is one of degree. Both react to the galvanic and faradic currents; the action of one is a quick, almost an instantaneous response, that of the other is slow.

When one pole or electrode is placed within a hollow muscular viscus as the stomach, rectum, or uterus, and the other externally, and the circuit closed, contraction of the viscus and also of the external muscles within the circuit will follow. Applications to the bladder can

be made directly by placing one electrode inside the organ and the other on the abdomen, or both externally, contractions being thus produced. The uterus responds to both currents and to either pole, the contraction being similar to that in other involuntary muscles.

The walls of the blood vessels contract slowly when currents are applied directly. The action is similar to that of ergot. When electric currents are applied externally clinical evidence shows that contraction of the small arteries is produced. The larger arteries, not having so much unstriped muscular fibers, do not respond so readily.

CHAPTER XXIII

NEURAL VIBRATION

269. Physiological vibratory action constituting nerve function may be divided as follows:

1. Simple polarization of the vibratory conductor. This, the primordial principle of all sensation, implies polarization of physiologic units or molecules—the neuromeres—constituting the conductor. It is a primordial state in development before conscious sensation arises and becomes specialized, and even before the neurone is evolved. In the simpler forms of animal life it is the only form of sensation; no doubt it is also a property of plants. In the neurone of common sensation and in all efferent neurones function seems to be effected by this form of vibratory action, the latter, however, being responsive to rhythmic stimulation. Its modification resides in its intensity and continuity. Polarization is the basic element of all neural vibratory action, including special sensation. The sensation of temperature belongs to the simple form, the change in temperature increasing or decreasing the pressure on the nerve-terminal or modifying the intermolecular spaces of the units, thus producing polarization. The heat movement is similar to that in crystallization and the principle is the same (§ 148, § 149).

2. *Polarization imparted to a neurone by an exciting substance in contact with its peripheral terminal.* Taste and smell are examples of this form of vibration. Smell is probably caused by radiant matter dissociated from the odorous substance (§ 143, § 353).

3. *Polarization imparted to a neurone, the excitation being caused by the wave motion of ponderable particles.* Hearing represents this form of vibration—an alternately accelerated and retarded polarization.

4. *Polarization of a neurone, the excitation being caused by wave motion in the medium of ether.* Sight represents this form of vibration—ether by displacement passing through the induced field of the free and initiatory unit excites it to polarization (§ 149), its distinctive character being its frequencies.

5. *Vibrations set up in the cerebral cortex by psychic influence.* These may belong to the first form of vibrations—simple polarization and depolarization of centrifugal neurones, as in the case of muscular contraction—or, accompanying polarization, vibrations—simple to and fro movement—may be sent out which give character to atoms, or ions (or their vibrations), engaged in metabolic processes (§ 231).

There are no known analogous external vibrations from which to judge the character of vibrations, imparting psychic influences to atoms, causing each cell to represent the individual beyond the amplitude of molecular potentials, and leading to hereditary characteristics.

As neural vibrations are accompanied by waste-dissociation, and as molecular dissociation must be accompanied by polarization, the conclusion is inevitable that each exciting vibration has a sequential polarization and depolarization of each neuromere within the excited neurone.

270. The vibratory movements of molecules are intimately related to electric action. We have seen that the trapeziform method (§ 46) of vibration transmits the galvanic current; and the faradic is a to and fro galvanic current produced through the phenomenon of induction. The trapeziform mode of vibration is essentially an alternate polarization and depolarization, and nerve vibratory actions must have this as a common element. The tetanic condition approaches a fixed polarization; but even in this there is a slight relaxation, which means depolarization. Molecular polarization proceeds along the neurone in wave form and the neuronal terminals are differentiated poles. Ciliary movement, as shown by the ovum traveling on its waves (§ 232), is really a trapeziform movement—alternate polarization and depolarization of the cilia (§ 46).

All molecules are capable of vibration, but they vibrate differently. Non-vibration is molecular death. On the other hand, the higher the potential—the life—of the molecules, the more sensitive they are in vibratory response. A vibratory molecule must have an inductive potential and must have an induced field, vibratory, or free space. The inductive potential of the molecule gives it vibratory sensitiveness, but the conduction of the vibration depends on the relative size of the molecule to its free space, and the proper adjustment of molecules in line. When the vibration is propagated by inherent potential, as in physiologic units, there must be a concentrative potential from which is furnished energy of propagation. In the latter case there is a complete polarization of the molecule with each vibratory movement, and the relative size of the ponderable molecule to the inductive potential influences its frequency. That molecules have

distinctive vibratory movement is evidenced by the differentiated color of matter.

271. There is no polarization of matter that is not accompanied by a corresponding polarization of the intermolecular ether. Free atomic ether—electrification—from its adhesion to material molecules must partake of all motor changes of the molecules adhered to (Fig. 2), and the material in an induced field, whether ether or ponderable matter, must respond to all vibratory stimulation that affect the primary potential, whether the potential is electric or chemic. Furthermore, it is clear that transmutation of vibratory action between molecular matter, molecular ether, and atomic ether must be reciprocal. This last postulate is of fundamental importance to a proper conception of electrical phenomena, and is self-evident when the relationship between the factors is studied (6, § 145). Reciprocal transmutation of vibratory action is well illustrated in the telephone (§ 146, § 147), and in the eye.

272. The external vibratory phenomena that produce impressions on the centripetal terminals of the nerves, and are thus conveyed to, and cognized by the sensorium, are objectively known as light, sound, odor and savor. The differences of these phenomena fundamentally depend on the distinctive characters of the vibratory act peculiar to each.

All sensation therefore is vibration, and the fundamental physiological difference is in the rapidity of the motion, in the intensity of the act, and in its continuous or rhythmic character. The conduction and appreciation of a vibratory act must take place through a similar act; therefore nerve tissue must be capable of vibrating in sympathy with external motor manifesta-

tions before cognizance can be taken of these phenomena. Hence, from the necessity of possessing differentiating powers we cannot see with our ears, nor hear with our eyes, nor smell, taste nor touch with our optic or auditory nerves. A state of incomplete differentiation between sight and hearing has been found to exist, which has been explained on the hypothesis that it is the survival of a primitive epoch, when such was the rule as regards all sensation.

Common sensation is vibratory in character, differing in simplicity and frequency from special sensation. Touch by compressing the tactile corpuscle polarizes the sensory neurone, and the simple degree of intensity or fixity of the polarization may be differentiated as a painful or pleasurable touch, just as the eye can appreciate a diffuse or intense light. In plants as well as in animals the property of molecular polarization exists, which in its simplicity is the primordial principle of all sensation. By molecular polarization sensitive polar fields are created, and the polarized mass assumes different forms both in vegetable and animal organization. In nerve tissue polarization of medium intensity is physiologic, an alternate polarization and depolarization, giving sufficient time for nutritional effects during the rest.

The difference between painful and pleasurable sensations is the difference in the continuity of polarization, pain being the manifestations of a tetanized nerve or of an intense induced field at the neurone-terminal, the result of polarized potentials, or of ions electrolyzed by intense or over action. In primordial conditions therefore all sensations are represented by the property of simple polarization, which by evolution and specialization become functions of more complex character,

but always retaining the common and fundamental property.

273. The physiologic action of the nerves of special sense is initiated by neuromere and neurone polarization, accompanied by the special vibratory characteristic of its specialized function; whilst the action of nerves of common sensation, and of efferent nerves—motor, etc.—merely polarize, a modification of the continuity and intensity of polarization indicating the degree of nerve action.

The functional power of differentiating between light and sound and between mere contact and odor or taste on the part of sensory terminals is not the limit of their discriminating action. They are to a large extent able to appreciate the most minute variations of vibratory action within their peculiar sphere, although there are light vibrations which cannot be seen and sound vibrations which cannot be heard. The intense power of selective action on the part of nerve tissue, and the influence of vibratory forces on nerve tissue and functions, afford physiologic proof of the therapeutic value of vibratory medicinal agents such as electricity, music, light, etc., and that in such agents we have a range of vibratory force capable of modifying numerous pathological conditions of the nervous system, requiring only judgment in choosing and setting the instrument, or in prescribing a vibratory agent capable of acting in sympathy with the particular case.

The change that takes place when an external becomes an internal vibratory action is merely one of medium. Light, the expression of a vibratory force in the medium of molecular ether, when reaching the surface of the retina, becomes a vibratory motion probably of the same period in sensitive molecules of the

filaments in the layer of the rods and cones, according to their individual differentiating power of interception. Through the structure of the retina it is conveyed along the optic nerve, thence to the optic thalami, and from these reflexly or directly to the cerebral cortex. Throughout its course the physiologic action must necessarily remain a vibration. It may lower or raise its frequency, modify its intensity, or change its medium of travel, but it still retains its essentially vibratory character, and each vibration must be accompanied by a complete molecular polarization with waste dissociation.

What applies to light vibrations in the sensation of sight equally applies to sound, odor, and taste, and their respective sensory vibrations. The common ground upon which all sensation stands is vibration, and the most important distinctive difference of the sensory movements is that of frequency, although the vibrations in light are continuous, while those of sound are intermittent or rhythmic. Therefore, from all parts of the body through the medium of the nerves, common and special, there are constantly arriving at the central ganglia, vibrations, which it is the functional property of the central or terminal units to differentiate and transpose. As we are able to judge of the character of the sensory action by a study of the force that acts on the periphery, so we may be able to form a conception of that psychic force, between which and nerve function there is reciprocal action and reaction, by a study of the physiologic action of the nerves themselves. If nerve function is fundamentally a vibratory action, psychic force must have a corresponding responsive action in order to appreciate vibratory variations.

We can explain by electric induction how a nerve unit in the spinal cord or cerebral ganglia can receive an impression from an afferent nerve, and convey an immediate impulse to an efferent, but there are no electrical phenomena to explain how a sensation can be transformed to psychic potential, and after an indefinite time how a resulting impulse is sent out through a different neurone. But a thought which may be regarded as the result of an external vibratory action, and the unit-manifestation of psychic force, may consist of a vibration in a medium more subtle than ether.

274. The first step in all nerve function is polarization, not only of the physiologic molecules, but of the conducting fibril or neurone. But although polarization is essential to and is the fundamental element of all nerve action, and in the case of some nerves may constitute, in its simplicity, the whole of the physiologic act, yet in the case at least of nerves of special sense, polarization is characterized by distinctive frequencies, accelerations and retardations, or even by reversed polar action, which are responses to external vibratory phenomena. These responses must correspond in character to the exciting vibrations. The difference between disgust and a pleasing taste, between an acid, a bitter, or a sweet one, is the difference in the rapidity or intensity of vibration. Material giving acid reactions may delay or inhibit normal polarization or have a tendency to produce reverse polarization. Touch, a slight impression on the skin, a kiss, sexual contact, or even a mutual glance, are the connecting of two systems of potentialed neurones which vibrate rapidly or slowly, polarize intensely or sluggishly, harmoniously or discordantly, setting up the

millions of variable sensations, pleasurable or painful; between all of which a highly evolved and sensitive nerve-unit is capable of discriminating. The conception is entertainable that between sensitive units in different individuals there may exist a sympathetic vibratory movement, which, radiating through the ether, are mutually interceptable and cognizable. There exists therefore in the units of conducting nerve tissue a physiological capacity of vibration, differing in different nerves or functional groups, having distinctive normal limits of frequencies and periods beyond which there exists either no response, or a responsive action which is so rapid or so slow as to be productive of pathologic results.

The physiologic variation in the retino-cerebral apparatus corresponds to that of light capable of affecting the eye physiologically; that of the auditory apparatus corresponds to the range of sound-appreciation; and that of other sensory nerves are analogous to their distinctive vibratory differentiations and capacities of response. Accordingly, by changing our field of vision from red to violet we about double the rapidity of vibrations in the optic, and there will be a much larger comparative change in the auditory nerve throughout the variation of its functional activity. A physical demonstration of different rapidities of vibratory action can be had in the resistance of the electrical current in different media; iron, for instance, offers a resistance six times as great as that of copper, that is, copper molecules vibrate six times faster than those of iron. The resistance can be decreased by increasing the cross-sectional area, that is, by increasing the number of molecules as vibratory carriers of atomic ether.

Color indicates the peculiar vibration taking place in the molecules of the substance, and points to all matter having as many distinctive molecular vibrations as there are varieties of color.

275. Some bodies can originate only one kind of vibration, and these can intercept only one kind, while origination and interception of vibrations of various periods are properties possessed by other bodies. This is the key to the whole problem of functional differentiation possessed by nerve structure, and it may also explain the selective action of drugs and other substances on the nervous system. The physiologic action of drugs exhibits peculiar selective properties which have been explained on the basis of chemical affinity. This implies a molecular decomposition, in other words destruction of the drug as such, but this is contradicted by elimination taking place to an extent approximating that of absorption in the case of some of these. Besides it is inconceivable that morphia and strychnia, being composed of the same ultimate atoms, differing slightly in relative number, and having the same chemical antidote in the oxidizing agency of permanganate of potassium, should have by means of chemic affinity and reciprocal dissociation opposing physiologic actions. Moreover the tissues themselves do not differ so widely in chemical construction as to warrant the belief that such a differential degree of action as that possessed, say by an anæsthetic, can take place through the medium of chemical exchange. Also, it must be kept in mind that function is not accompanied by chemic action between molecules, but a dissociation from one molecule—the physiologic unit. Chemic action between another molecule and the unit would be destructive of the latter. Clearly the explana-

tion of the selective action of drugs must be sought for in a different direction. In the distinctive vibratory capacity of neurones and in the comprehensive variation of vibratory frequencies of the whole nervous system, as proved by its power of differentiation of external vibratory phenomena, on the one hand; and in the fact that all matter, organic or inorganic, differs in the rapidities of its molecular vibrations on the other hand, we have a rational explanation of the action of many medicinal agents.

276. The properties of calorescence and fluorescence possessed by certain substances typify the action of drugs in modifying or nullifying nerve action. Platinum and lime, for instance, under certain conditions, have the property of raising the refrangibility of obscure rays of the infra-red variety so that they become luminous. On the contrary, as shown by an ordinary spectrum, a solution of the sulphate of quinine will lower the rate of vibration in an ultra-violet ray to a period appreciable to the eye as light. Could there be a clearer demonstration of the action of quinine as an anti-pyretic than the simple fact of its possessing this fluorescent property? If it synchronise ether vibrations outside the human body, it will hardly be denied that it can do so inside. Again, the enzymes (§ 212) present a type of action which no doubt represents nerve stimulants such as strychnia.

It is apparent that a body with an intense induced field will, according to its potential, inductively electrify all polarizable bodies within its area. Figure 122 represents a strychnia molecule with its magnetic field. (§ 19.) A salt of strychnia introduced into the body being entirely soluble, is equally present in all parts of the circulation, but its selective action is on the spinal

cord, and particularly on the multipolar ganglia in the anterior horns of the cord. Its action is distinctly calorescent. A few strychnia molecules coming in contact with the dendritic processes of one of the centers inductively polarize the fibril, and raise the latter's vibratory action to accord with that of strychnia vibration. Each additional molecule of strychnia arriving at the scene of action is like adding an additional electro-motive force to an electric current, and this goes on until the vibratory action of the nerve passes the physiologic limit, and there is a tonic contraction

Fig. 122.

Organic Molecule of Negative Potential $C_nH_nN_nP_nO_n$.

Strychnia Molecule $C_{21}H_{22}N_2O_2$. 333.31 Positive Potential.

Chloroform Molecule $C\,H\,Cl_3$. 119.08. Negative Potential.

of the muscle as in the administration of a powerful galvanic current. Each strychnia molecule, after doing its work and undergoing no chemical change as a result, is absorbed by the lymphatics to be eliminated, or again and again by circulatory influences to be brought back as a reinforcement to others.

277. The rapidity of the vibrations of morphia is much lower than that of the vibrations of strychnia, and slower than the vibratory action of most nerve tissue, although its stimulating action in small doses proves its power of raising the rate of vibrations of certain centers. However, the principal action of morphia is to obstruct nervous vibrations or to lower the molec-

ular movement to periods synchronous with its own molecules. The formula of morphine is given as follows:

$$C_{17}H_{19}N\ O_3 + H_2O. \quad \text{Molecular weight, } 302.34.$$

In its negativities and positivities the morphine molecule is more evenly balanced than the strychnia molecule. Under polarization it has four oxygen atoms, and oxygen is the most negative of all the elements. These partly balance the positive character of other atoms, which are less numerous than those of strychnia. The potential of the morphine molecule resides in the number of atoms in its construction or potential of concentrativeness; the inductive potential, however, is of positive character, but its positivity is not so pronounced as in the case of the strychnia molecule. Upon the positivity or alkaloidal character of morphia rests its initiatory stimulus to nerve action; and upon its producing a vibratory block, by interfering with the association of molecules of polarization, depends its narcotic properties. It stimulates a terminal in the endocardium by re-enforcing the electro-positivity of the blood-serum, and blocks the polarization of physiologic units when mixing with nutritional elements.

The vibratile movements of strychnia, morphine, and chloroform as shown by their physiologic action on nerve tissue, illustrate in a marked degree the relationship between the vibratory action and the qualitative and quantitative potential of molecules.

278. Cocaine is opaque to certain vibrations—those of the peripheral nerve terminals—just as certain bodies are opaque to certain lights; thus by inserting itself into the conducting nerve tissue it prevents the propagation of the particular rays of energy of which sensory nerves are conductors. A cocaine molecule,

inserting itself between the molecules or physiologic units of the polarizing elements of peripheral sensory nerve-fibrils, interferes with the rhythm of the trapeziform movement of these elements (§ 7, § 174, § 175). Curare, on the other hand, causes a block of the motor wave-vibration, probably at the motor plate.

279. Chloroform, $CHCl_3$, has large potential of negative quality. The hydrogen atom is specifically positive. The carbon atom is qualitatively equipotential or feebly positive. Chlorine has a large negative potential, which when multiplied three times gives the molecule of chloroform an intense negativity with a large induced field (Fig. 122). The potential of concentrativeness of chloroform is small in comparison to organic molecules.

By inhalation chloroform is absorbed into the blood by osmotic action, the negativity of chloroform and the positivity of the blood creating a physical attraction. Perhaps the pulmonary polar arrangement assists osmosis. The mutual attraction does not appear to be sufficient to cause a chemic reaction. Nevertheless chloroform is capable of partially or wholly neutralizing, through its vibratile action, the vibrations of the positivities resident in the alkalinity of the blood. A concentrated inhalation takes vibratile possession of the blood and cuts off the vibratory stimulus of the respiratory reflex. Chloroform occupies the induced fields of electro-positive blood-elements, and neutralizes positive stimulus. However, the surface of the lung is so large that there is generally sufficient normal vibration of positive character in some part of its circulation as to make the danger comparatively small. Further, the blood constantly reaching the lung is free from chloroform. The normal vibratile stimulus of respiratory

movements depends on the alkalinity of the blood, and not on the presence of carbon dioxide (§ 233, § 236).

When the blood containing chloroform fills up the cardiac cavities, pressing at the distolic height equally on all parts of the endocardium, in which terminate the afferent fibers of the pneumogastric, the chloroform retards or inhibits normal polarization; or, if concentrated, it stimulates the fibers to polarize reversely, that is, with their positive poles toward the negative chloroform, just as in the case of an electric stimulus to a divided pneumogastric (§ 261, § 264), and the result is exactly the same in both cases. The endocardiac nerve terminals become abnormally and positively charged, their positive molecular poles turn towards the endocardiac surface—towards chloroform negativities—the cardiac neural pathways are reversely polarized, the impulse nerve tract is blocked, and the muscle of the heart is said to be paralyzed.

All nerve centers or terminals, having negative molecular potentials, and negative leading off points, and thus requiring positive stimulation, are affected sedatively by the vibratile negativity of chloroform. The intensity of chloroform action is modified by the circulatory distance of the center from the lung, thus allowing the chloroform to become diluted, and by the distinctive frequency of vibration that characterizes the nerve center.

Chloroform may interfere with polarization of the muscle-disc by taking possession of the associating molecules of polarization, and may even block nutrition by occupying the induced fields of nutritive elements such as glucose-molecules, thus temporarily weakening the cardiac muscle. These actions must be accomplished in the blood as it passes through the cardiac

nutrient artery. It may also interfere with association of molecules of polarization of the nerve units.

280. Alcohol is electro-positive in its molecular inductive potential. The alcohol molecule has more positivities and less negativities than chloroform; when broken up by chemic action alcohol furnishes ether from its molecular induced fields. The stimulating action of alcohol depends on its oxidation and formation of simpler compounds, thus setting free energy, and on its vibratory positivities, thus assisting the normal action of the blood. Chemic dissociation evidently takes place in the circulation, especially in that of the lung, thus differing from nutritive molecules, the dissociation of which takes place in the tissues. When taken in quantities beyond the power of oxidation alcohol is sedative through over stimulation and through blocking the processes of nutrition, and interfering with the absorption of the associating molecules of polarization.

281. The author formulates the following law in regard to the vibratile action of medicinal agents: An inductive potential acts aggressively on the vibrations of the tissues, but the aggression is differentiated as to positivity or negativity: (1) As to the quality of the molecules of the agent, and (2) as to the quality of the molecules of the tissues. As the leading off point of conducting nerve-tissue is always negative, it follows that positive potential is the physiologically vibratory stimulant to nerve action, as stimulation is accomplished under the law of unlikes attracting (§ 234, § 235). Again, vibratory frequencies increase, decrease or block nerve vibration through their fluorescent or calorescent properties, or through their differentiated rhythm (§ 253).

The vibratory zero resides in the molecule of ether. Vibratory potential increases towards positivity or negativity according to the character of the molecules (§ 19, 20). Responsive sensitiveness is in direct proportion to the potential of the molecule and inversely to the molecular weight (§ 1, § 253); but the frequencies appear to depend upon a specific balance of these factors. The molecule of ether, having no molecular weight and no potential, is only capable of imparting vibrations by propagation through its impenetrability and elasticity; but when ether is polarized it has a potential, and still having no molecular weight, it is extremely sensitive to vibratory influence. Consequently the induced electric or magnetic fields of charged bodies and of molecules of high potential are extremely sensitive to vibratory influence.

Vibratory medicinal agents include a large number of drugs, such as ergot, digitalis, belladonna, ether, aconite, etc., but the scope of this work will not permit of the discussion of their action in detail.

282. Closely connected with this part of the subject are stimulation and inhibition of muscular action through the medium of the nerves. The slowing or quickening of the heart's action by stimulating the pneumogastric or vaso-motor nerves, has been explained by the author in previous writings on the hypothesis that there exists a different rate of vibration in the axis cylinder of these nerves, and that their respective periods are in part complementary, their union thus producing a result similar to interference in the phenomena of light and sound. The explanation of inhibition has been given in this work (§ 264) as *an efferent impulse in an afferent nerve*, the impulse

taking possession of the leading off point in the field where the physiologic vibration is initiated.

283. Heat or cold applied to the body influences the molecular vibratory action of the part to accord with that of the application, and although a poultice will relieve pain, it does so probably by hastening absorption or relaxing the tissues, whereas ice relieves by lowering vibration directly.

Pleasure may be described as a heightening of vibration within the physiologic variation; pain as a disturbance of vibration outside of the physiologic capacity, or as a tetanic condition of the nerve—a continued polarization, or with slightly intermittent depolarization. If pleasurable vibrations are prolonged beyond the power of the system to equilibrate them, or of nutrition to maintain the molecular potential, they will end in pain. Physical pain, anger, impatience, are accompanied by excessive vibration; while fear, sorrow, and depression decrease the normal rate, or produce a state of depolarization with slight responsive capacity for polarization. A person with toothache going to the dentist, his nerve-molecules vibrating abnormally high on account of the pain, thinks of having the tooth extracted, and the fear of such an operation immediately lowers the rate of vibration, and thus for the time the ache ceases. In a neural pathway the proximate terminals of certain neurones may be so relatively placed to the distal terminals of other neurones as to intercept stimuli from two or more sources; and it is obvious that vibrations of different characters may arrive at a neural station, which may increase or decrease the frequency, or disturb the rhythm of the normal vibrations of the pathway. Some of these extraneous vibrations may express joy, and

others despair; in fact there may be as many by-paths with distinctive vibratory characters as there are sentimental expressions. An irritable or irregular heart-beat may be the resultant of confluent vibrations modifying the normal rhythm of the cardiac cycle; and the painful vibrations of a neurone may be allayed by the blending of less frequent vibrations. Clearly, although nerve fibers do not anastomose nerve currents are confluent. It is a physiological but not an anatomical anastomosis.

284. The whole nervous system, like the circulatory, in the vibratory sense is undoubtedly continuous. By introducing into the latter a soluble substance, it permeates every part of the body, selecting certain structures which are acted upon according to chemical and other laws; it is the same when a vibration enters, by sight, hearing, smell, taste or touch, into the grand continuous trunk of nerve potentials or vibratory nerve structures. The vibration, according to its period, has a direct selective and modifying influence on the emotions, intellect, sentiments, or on the circulatory, respiratory, absorptive or eliminative apparatus; in fact, on every vibratory motion that goes to make up the personality of the individual. Sound entering this channel of nerve force affects the system according as it is high, deep or medium. The shoveling of coal on the sidewalk, the sharpening of a saw, and the voices of some people rasp every sensitive nerve filament; while other voices, other tones, bring into physiologically harmonious action the whole vibratory system. A sound vibration travels along the auditory nerve with distinctive polarizing rhythm. At the auditory central terminals alternate polarizations and depolarizations rhythmically affect the proximate cen-

trifugal terminals, which respond accordingly; the alternate action of polarization and depolarization in the auditory nerve, being effected by, and in harmony with, the external sound-vibrations, are thus propagated through all pathways. Between the afferent path in the auditory nerve and the efferent motor pathway, music travels through the psychic region, or may be switched off into this region, thus producing mental effects according to its character and the responsive potentials of cerebral units.

285. It is the same with colors, although in a less degree; and green, which stands in the middle in vibrating strength and is the prevailing color in the activities of nature, is probably the best borne by the eye; and it has been asserted that the rapid vibrations of violet, blue, and green light, have a calming effect; and the less rapid red has an exciting effect on the nervous system. The effect of light on animal growth differs in relation to the vibratory frequencies and to the kind of animal. The vitality of most animals is stimulated by exposure to violet; but silk-worms grow less rapidly in violet light than in the lower light vibrations. That a bull is excited by red and a horse quieted by blue can only be explained by the accord and discord of light and nerve vibrations.

286. Music is perhaps the most emotionally stirring of all the arts; moreover musical sound of all oscillatory motions which influence nerve action, produces the most deep, intense and varied responsive expressions, and the explanation of this can be given, not from the metaphysical aspect, but from the physical character of its workings. If the possible variation in the rapidity of vibrations in most nerve tissues conforms with the variation existing in sound between the

highest and the lowest pitch, such conformity will account for the sympathy existing between nerve vibration and music. With simple rhythmic sounds the aborigines of North America are able to intoxicate themselves for hours, while a sensitive and cultivated musician may be thrown into convulsions by a too marked discord.

Music, according to the instrument, voice, tune, melody, rhythm or tonality, produces joy, sadness, tenderness, tears, laughter, tranquillity or uneasiness; the result also depending on the physiologic and physical conditions. That the effects produced by music are primarily physical has been conclusively proved by experiments on animals, they being particularly sensitive to rhythm; and from observations on man from the savage to the cultivated amateur, all being sensitive, differing only in degree.

Music as a vibratory remedial agent ought to have a wide field of usefulness. According to the rhythm, harmony or discord, it dilates or contracts the arterioles, quickens or retards the heart's action; thus regulating the blood supply, modifying nutrition and inducing a healthy metabolism. It slows or stimulates the respiratory movements, bringing about a healthy oxidation of the tissues and arousing the lethargic. Acute sounds, like the break in an electric current, will cause muscular contraction, and the motor and sensory nerves respond to stimulating music, thus acting as a massage and producing local development. It acts indirectly, if not directly, on all vital functions, and if correctly used its tendency is always toward the normal in its results. Shocks, sweating, thrills, horripilation, are symptoms which attest its intensity. In emotional disturbances, mental exhaustion, insomnia, hysteria, hy-

pochondria, and in all those conditions where prolonged vibrations have exceeded the equilibrating processes, and which if continued might lay the foundation of a future insanity, music of one kind or another is indicated as a curative and prophylactic agent.

The soothing influence of consonances and the stimulating action of dissonances, the more exciting major key and the less exciting minor, can be made use of to produce differential results, according as an anti-spasmodic, calmative or exalting effect is needed. In fact, each tone has its peculiar significance, requiring only a correct interpretation to be successfully applied to the pathological vibratory disturbance, where it is indicated for its healthy modification.

287. Of all external vibratory forces that influence internal molecular vibrations, electricity is one of the most valuable for therapeutic purposes. It can be given in just as exact dosage as drugs; and it always remains under the control of the administrator, and its action commenced or stopped at pleasure. It can be made general or local in its application at the will of the operator; and it can be used for its chemical, electrotonic, tonic, stimulating or antispasmodic effects; in short, electricity will quicken or retard all functional vibratory actions of the human system.

Electro-neuro-muscular vibratory phenomena fully accord with the differential effects produced by light and sound frequencies on the nervous system. The general law governing the physiological action of frequencies may be thus formulated: *Comparatively high, unvarying or gradually varying frequencies of vibration, are calming or even anesthetic; whilst slow or abruptly varying frequencies are exciting.*

CHAPTER XXIV

Sleep

288. After a period of nerve action there is loss of potential in the nerve-unit; and it is necessary that rest should follow in order that what has been lost may be made good. It is not enough that there is rest of individual neurones following an effort, but a complete periodic relaxation of all neurones, more or less, of the cerebro-spinal system, with slowing of the respiratory and circulatory movements, and with diminished secretion and excretion, is essential in maintaining the physiologic equilibrium. Sleep therefore is a slowing of the processes of life accompanied by general recuperation. The work performed causes a loss of molecular potential and lessens the intensity of nervous response, conditions inducive of sleep; at the same time outside stimuli may be reduced to a minimum by modifying environing conditions. The loss of potential is not confined to nerve-conducting structure, but extends to the reservoirs of energy in the nerve-cells and to the stored potentials in the blood (§ 162). Consequently the exercise of one nerve or group of nerves or muscles cuts off the supply of energy of all by depleting the common storehouse. Hence the general cause of rest in the cerebro-spinal system during sleep is the loss of potential energy in the blood, and from this central

cause ensues the slowing of the circulation and general decrease of functional activity.

During sleep the blood recuperates by gland-cell action (§ 215) and by other nutritive processes; energy is stored up in the nerve-cells; and the conducting fibers regain their potential.

What change takes place in the nervous system when it passes from a condition of action into one of sleep? As has been pointed out, the first step from rest to action that takes place in the nerve is polarization, so the first step towards general rest or sleep is depolarization of the nervous elements, or physiologic units. Continued depolarization of nerve tissue such as takes place during the period of sleep is merely an extension of the period of the intermittent depolarization such as takes place in the respiratory and circulatory neuromuscular apparatus. In fact all nerves polarize and depolarize while performing their various functions. The cause of the intermittent action of the respiratory and circulatory organs continuing during sleep is the fact of the continued presence of exciting influence; although these influences are lessened by the lessening of the other vital processes.

No doubt the chemical changes that take place during nerve action favor depolarization; and the presence of carbon dioxide, one of the results of these changes, has been assigned as the cause of sleep; but this is only one of the many chemical changes in the metabolism of vital tissue, and its presence interferes with rather than assists recuperation. The fundamental and general condition during sleep is depolarization of conducting nerve-units, and this is favored by wear and tear during physiologic action; and assisted by excluding exciting causes of nerve polarization.

When during sleep individual neurones or groups of neurones polarize they spin out vibrations from central storehouses of vibratile energy, and the sleeper dreams.

Hypnosis

289. A condition which to some extent appears similar to sleep, but which has none of the superficial signs of the latter, has been called hypnosis. The essential elements seem to be a fixity of attention and obedience to stimuli. A hypnotized person is in a passive state, and under the influence of the hypnotizer, and believes everything that the hypnotizer tells or suggests to him. This is different from sleep, in fact the state of hypnosis is fundamentally the opposite of sleep, sleep being a state of depolarization, and hypnosis a state of *fixed polarization*, at least of part of the nervous system of the hypnotized individual, with his nerve vibrations acting in sympathy with those of the hypnotizer. Hypnosis is a tetany of a certain nerve or group of nerves, and the polarizing excitant is suggestive influence. Further the suggestion is accompanied by a fixity of polarization of the hypnotizer's nerves by an intensity of psychic force. It is a higher potential taking possession of a lower, but the two potentials must have a sympathetic rate of vibration as in transmission by wireless telegraphy.

CHAPTER XXV

The Human Body as an Electric Conductor

290. The relative conductivity of the human body as a whole to other conductors has been stated (§ 5). We have now to consider the relative position of the individual tissues to each other as conductors. It has been shown that a saline solution stands next to metals in the possession of this property, and that the body as a whole is a much better conductor than pure water when the skin is sufficiently moistened; but is not so good as a saline solution.

The following table gives the quantities of water in the most important tissues:

TABLE OF QUANTITY OF WATER

Tissues		*Parts of Water per 1000*
Bones		130
Tendons	(Burdach)	500
Skin	(Weinholt)	575
Liver	(Von Bebra)	760
Muscles	(Von Bebra)	725
Ligaments	(Chevreal)	768
Blood	(Becquerel & Rodier)	780
Cerebral gray matter	(Lassaig)	850
Cerebral white matter	(Lassaig)	730
Spinal gray matter	(Le Herit)	710
Spinal white matter	(Von Bebra)	650
Nerve matter	(Ranke)	770

This table is important because it shows that the tissues may be considered as imbedded in water, or in a saline solution, as saline matter is always present. As saline solutions are the best electric conductors of all the body substances, it follows that the greater the percentage of water, with its contained salts, in the tissue the better it acts as a conductor.

As the electric current moves in the line of least resistance, a knowledge of the percentage of the water in individual tissues is important in directing the electric applications. The current in passing through the body takes the line of least resistance; but resistance is inversely proportional to the cross sectional area, and directly proportional to the length. The direction of the current therefore is a compromise result of these laws. In order to enlarge the cross sectional area the current will spread; to decrease the length the current will seek the nearest route; and it will also seek to travel through the tissues having the least electric resistance; the practical result being a compromise between these factors.

291. Although the tissues of the body are fairly good conductors, they are many millions times worse conductors than the metals, the property of conduction requiring that the molecules should swing not only freely on their axis, but that the swing and the intermolecular space should conform in dimensions, and that the vibratile rhythm should be uniform. The molecules of dry air no doubt swing as freely as those of copper, but the intermolecular spaces in air being larger, and the rotary movement not being sufficient to reach across, they have to move bodily backward and forward to span the interspace, which means additional work and therefore resistance. The addition of an alkali to water gives

the water an increased density, a step towards fixity of the molecules, and intensifies the property of conduction. Molecules of air-elements may be charged, and move forward with the charge, similarly to what takes place in liquids.

Another consideration is uniformity in the arrangement of molecules, which must be deficient in liquids, and more particularly in semi-solids and in the multiple tissues of an organic body. The want of uniformity in the arrangement of molecules in tissues accounts for the current increasing after passing through the

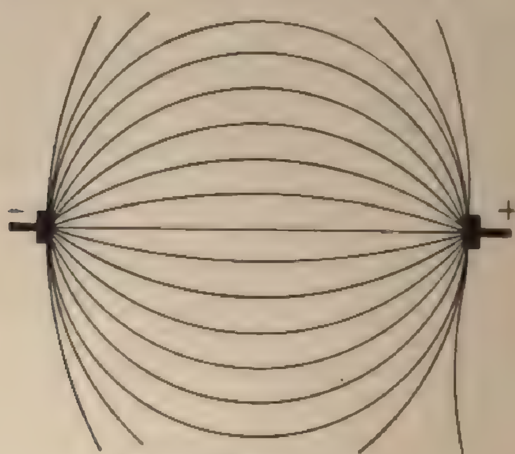


Fig. 123.
Distribution of a Current in a Uniform Medium.

body for a short time. The passage effects molecular polarization in uniform line, thus lessening the resistance.

The electrolytic action taking place in the tissues creates a chemical potential which acts against the passing current, but the increase of current after applying it for a short time, and the maintenance of its rate afterwards, shows that practically speaking, for the

length of the ordinary seance, this need not be taken into account.

292. *Density.* By density is meant the quantity of electricity passing through a given cross-sectional area at any moment. Electricity may be compared to a river which flows through a narrow passage, spreading out on a plain, and then collecting its waters to flow through another narrow at the opposite side. In the spreading of its water on the plain the river cuts a channel here, and leaves an island there, according to the resistance made to its force, but the waters collect at the strait beyond and rush on with increased speed.

So it is with electricity: It passes through an electrode, spreads out in the body according to the law of resistances, leaves a bone untouched as water leaves an island, and concentrating in tissues of less resistance tears the unstable molecule apart by electrolytic action, and carries another along by cataphoresis, and condenses at the opposite electrode as does the stream at the narrow.

PART III

ELECTRO-PATHOLOGY

CHAPTER XXVI

293. A scientific therapy demands an exact knowledge of the fundamental pathologic conditions which it is desired to normalize. This is as true as the converse, that the action and character of the therapeutic agent must be understood in its differential relationship to physiologic and pathologic conditions. In this chapter only such diseases will be referred to whose pathologies can be cleared up by approaching them from the standpoint of the fundamental principles laid down in this work.

NEURASTHENIA

The katabolic changes that immediately result from nerve action must necessarily take place in the conducting fibrilla of nerve structure. This change is analogous to electrolysis, each molecule being an electrolyte. But there is this difference between electrolysis and nerve action: In the former the decomposing force is from an external source, while in the latter each molecule has its own potential or stored energy requiring only a slight excitant to set it free. The

katabolism which occurs during polarization or nerve action is at the expense of the molecular potential of the conductor, and consists of oxygen, hydrogen and carbon ions dissociated from the nerve unit or molecule of the neuromere. During depolarization or nerve rest the conducting molecule regains its potential by receiving molecular nutriment from the surrounding protoplasm or hydro-carbons, probably for the most part stored within the nerve cell. In order to keep up the physiologic supply of nutrition the storehouses draw on the blood.

It will be seen that neurasthenia may be produced by an excessive katabolism or breaking down, or a deficient anabolism or building up, and both of these processes may involve the blood. The latter, commencing in the blood, extends to the conducting fibrilla; and the former, commencing in the conducting fibrilla, extends to the blood.

Neurasthenia is a loss of potential on the part of the conducting molecule from excessive action or from a deficiency in the supply of nerve nutriment; which may be accompanied by the accumulation of katabolites which clog physiologic action. Specifically, the nerve-molecule by a loss of atoms—carbon, hydrogen and oxygen—is reduced in size, has a lessened actual negative potential, also a lessened vibratory resistance owing to decreased dimensions, has lessened intrinsic and extrinsic pressure, and loses its physiologic equipoise; consequently the irritability is greater although its force and power of endurance are lessened. The irritability is also increased by a concurrent impairment of insulation of neurone-terminals, as in hysteria.

Excess of uric acid, the result of katabolic metamorphosis accompanying neurasthenic conditions, may

cause gout, which may be thus related to neurasthenia. Moreover the neurasthenic changes in the blood may cause degenerative changes in the heart, blood vessels, kidneys and other viscera, in the end constituting a general breakdown.

Hysteria

294. That the ultimate nerve fibril is an elongated body capable of polarization, and made up of neuromeres also polarizable, is at least probable. No other hypothesis can explain the multitudinous physiologic and pathologic phenomena of the nervous system (§ 170).

It has been pointed out that each molecule is an electrolyte (§ 160). Moreover the neurone is a larger electrolyte, with an inherent electrolytic force within the potential of its molecules. Thus there are the following considerations: (1) During physiologic action, each molecule having poles, the neurone must have poles as in a magnet, the waste ions uniting at the poles of each molecule and the energy diffusing as heat; (2) an increased polarized action may allow the ions to unite but cause polarization of the freed energy, the neurone becoming charged similarly to an induced electric conductor; (3) during tetanized action the ions may be polarized and accumulate at the poles of the neurone, which is thus constituted an electrolyte. Upon these principles are based physiologic and pathologic reflex actions. Thus at the distal terminal of a neurone there may be the potential of a magnet (physiologic); or a potential as in the induced electric conductor, or chemic potentials as in the electrolyte (pathologic). As the leading off point of the neural wave is negative the distal end of the neurone during

action is positive. During extreme tetany oxygen may accumulate at the proximate end, and hydrogen and carbon at the distal, by direct dissociation from the terminal neuromeres. During an abnormal increased action short of tetany the ions may unite and carbon dioxide may accumulate by induction at the distal, and water at the proximate end of the neurone. Still lessened but abnormally increased action the terminals may be electrically charged.

In normal action during depolarization all increased potentials neutralize within the structure of the neurone—transformed into heat. Electric or chemic potentials created during action at the terminals of adjoining neurones will neutralize, by passing through the myelin covering, if insulation is imperfect, thus constituting a leakage. Moreover, continued nerve action favors imperfect insulation. This method of neutralization is analogous to electric rupture or leakage. Leakage at one center disturbs the equilibrium more or less of the whole nervous system.

The essential morbid entity, which constitutes the distinctive pathologic condition giving rise to the multiplicity of symptoms represented as hysteria, must of necessity be central in location. No gross lesion can be detected, but a hypothesis can be advanced, on the basis of molecular changes, to account for the peculiar phenomena characterizing the disease. A weakening of some part of the nerve structure, eventuating from acute disease or hereditary tendencies, predisposes toward hysteria. No lesion of the conducting part of nerve structure, whether it be physical or chemical, accounts for the variety of symptoms. There may be hyperirritability, but that is more often an effect than a cause, and even when pronounced it does not consti-

tute the principal manifestation. On the other hand, a change taking place in the molecular arrangement in the insulating part of the nerve structure, thereby lessening its functional power, and allowing an escape of nerve force in an abnormal direction, will upset the whole systemic equilibrium, thus explaining the diverse character of the symptoms.

Whether the property of insulation resides in the white substance of Schwann, or in the myelin coating of cerebral fibers, or in the neuroglia, or whether it pertains to the axioplasm or neuroplasm of Waldeyer and Kœlliker, has not been decided by physiologic or anatomic research. Neither does pathology by itself furnish a solution of the problem. A fact having an important bearing on the subject is that, with the exception of the neuroglia, the parts of the nerve structure mentioned are the first to show degenerative changes, and, therefore, the first to be functionally weakened when encroached upon by dyscrasias or hereditary taints. The neuroglia under pathologic conditions usually proliferates, thus resembling connective tissue, but, unlike the latter, it is of epiblastic origin, and therefore may be possessed of the function of the connective tissue, combined with the property of insulation.

The study of degenerative processes in nerve structure, when there is a complete solution of the continuity of the nerve trunk, when the nerve is encroached upon by disease as in the spinal column, or when there are pathologic changes affecting the cerebral cells, show that the initiatory step of degeneration is taken, not in the conducting fibrillæ, but in their immediate surrounding investments—the medullary layer or proto-

plasmic elements—which, of necessity, must have insulating properties.

A study of dielectric media gives a clue to the insulating properties of organic tissue. By specific inductive capacity is meant that quality possessed by media of modifying the potential between two charged bodies, the charges on the bodies remaining the same. Thus with air as unity the following table gives the dielectric constants of the substances named:

Substance	*Dielectric constant*
Sulphur	2.58
Carbon disulphide	1.81
Hydrogen	0.999674
Carbon dioxide	1.0008

If there is a given charge on two bodies at a given distance apart, and sulphur is the dielectric medium, there will be a certain difference of potential between the charged bodies. This difference of potential will be increased immensely by substituting carbon dioxide or hydrogen as the dielectric medium. The substitution is equal to multiplying the charge by two and one-half (§ 101).

The organic substance neuro-keratin is found in the brain and in the medullary sheath of nerve fibers. It contains a large proportion of sulphur and is probably possessed of insulating properties. Sulphur then has very great specific inductive capacity, and is one of the constituents of neuro-keratin, a substance found in the medullary sheath of nerves, a structure placed in a relative position to the axis cylinder to enable it to insulate the latter. Moreover, the medullary sheath is the first part of nerve-structure to show the effects of degenerative processes. The terminals of neurones

may be considered during action as charged bodies having magnetic, electric or chemic potentials, divided by insulating or dielectric media, and it is probable that the dielectric is a compound in which sulphur is held loosely and in large proportion. It is evident that if the dielectric structure is altered by degeneration the difference of potential between the charged terminals will be modified. We know that the amount of sulphur in the urine is increased in dyspnœa, that is, the accumulation of carbon dioxide in the circulation increases the elimination of sulphur. We know also that in asphyxia of animals, by placing them in a closed cage and depriving them of air, convulsions are produced. Is not the immediate cause of these convulsions the replacement of the sulphur in the neurokeratin by carbon dioxide, thereby increasing the potental charge of nerve terminals?

It is possible and probable that what takes place in certain centers during excess of nerve action is as follows: Carbon dioxide is polarized at the distal terminal of the neurone, or the dissociated hydrogen and carbon accumulate, and chemically act on the neurokeratin and displace its sulphur, and by this metabolism the dielectric specific inductive capacity is decreased, the difference of potential of the terminals is immensely raised, and even electric rupture or leakage may follow.

In Fig. 124 the lines, AA, represent a nerve tract, showing same pathway under differential potentials; the first part, B, indicates normal action, the poles of the neurone having similar potentials to those of a magnet; C, the results of an excessive nerve action in which ions neutralize at the poles of the neuromeres and accumulate by induction at the poles of the neurone, as water at the negative and carbon dioxide at the positive, the

condition being slightly sedative to the propagation of nerve-force, just as an induction-coil is sedative to a primary current; D, polar electric potentials by induction from ether set free by union of ions of waste, and as the condition is sedative to nerve-action the projection fiber is shown as normal, the induced positive ether being at the negative, and the induced negative at the

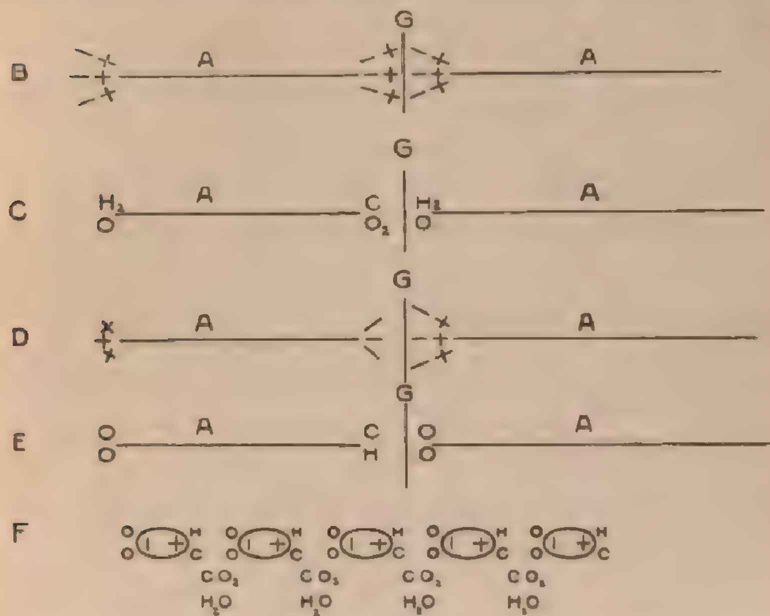


Fig. 124.

Differential Polar Potentials of a Neural Pathway. The potentials indicated as C, D and E, are secondary to the primary potential, B.

positive pole of the neurone; E, oxygen at the negative pole and carbon and hydrogen at the positive in the position in which they are dissociated from the nerve-unit, and at which they are accumulative under intense action; F, the same as E, indicating the process of accumulation of the ions at the poles of the neurone, whilst neutralizing at the adjoining poles of interpolar neuro-

meres (§ 160), the polar condition being an intense stimulus to an already stimulated nerve; G, myelin or neuroglia in the position of an insulator between the terminals of neurones. That the several conditions are possible is evidenced by electric and physiologic facts. For example it is seen that carbon dioxide passes into the blood during gastric activity, and that it passes outward in the bile through hepatic activity, and there is no doubt but that polarization of glands is the main factor of the differentiation. The sensitiveness of ether and ions to polarization is shown by the action of electric cells and by electrolysis; whilst there are many examples of ions being broken off at polar terminals of circuits and carried across the gap. Each condition obtains as a result of a specific degree of nerve action, and the relative intensities are probably in the order of placement indicated in the figure B, representing normal and the other parts more or less abnormal activities.

In a neurone subject to constant stimulation with periodical exacerbations, carbon dioxide will inductively accumulate at the distal pole with periodical aggregation of the ions, hydrogen and carbon, by direct dissociation from the terminal neuromere. These elements being impelled against the insulating wall, the bombardment must impair its property by dissolving sulphur from the neuro-keratin upon which insulation depends. During normal action the polar ions neutralize by displacement within the structure of the neurone in a similar manner to the displacement-movement occurring in a Daniell cell, but if insulation is impaired the ions will neutralize by reactions between those of the positive pole of one neurone and those of the negative poles of adjoining neurones.

What constitutes a fulgurating center is not only an escape of nerve force from one neurone to another, or to others, but an actual shower of ions piercing the insulating barrier and neutralizing ions of opposite quality at the opposite pole of a neurone, or poles of neurones, in juxtaposition. The neutralization occurring at one center causes the propagation of the condition to other centers of reflex action. Neutralization in this case takes place between neurones as it does between neuromeres. This leads to the conception that the insulator is a bar thrown across the neural path to check an increasingly accumulating force of the neural wave, and thus equilibrate nerve action. In a pathological condition, however, this bar may dam the ions until they break loose in a flood. Specifically the ions, hydrogen and carbon, at the distal pole of a neurone pass through the insulator and neutralize the ions of oxygen at the proximate pole of the extension-neurone; hence the positive ions of the extension-neurone must react on the insulation and negative ions of proximate terminals of secondary extension-neurones. No doubt the points of insulation at nerve terminals are centers of differential distribution through the relative intensities of action and sequential areas of induction; but an impulse differentiates its pathway, in obedience to the will, from a selective faculty of which cerebral terminal units, delicately differentiated in potential, in relative distances asunder, and consequently in responsive action, are the receptive seat.

295. The afferent and efferent nerve fibers, constituting the sensory and motor pathways, leading to and from the cortex, converge to form the greater part of the crura cerebri, and a large proportion of the afferent fibers are connected with the basal

ganglia. The optic tract, passing backward toward the occipital lobe, is intimately connected with these ganglia, and the other nerves of special sense are also connected. Therefore this region of the brain is the great crossroads of the nervous system, and, notwithstanding the intense anatomical and physiological congestion, each fiber and cell must be completely insulated from their proximate fellows. It is in this region, therefore, that a slight degeneration of the insulating tissue has telling effects; and it is in this region that such a molecular change will account for the peculiar and varied symptoms characterizing hysteria. The diagram (Fig. 125) illustrates the sequential order of phenomenal manifestations. In Fig. 125, the neural pole, P, represents a point of irritation by trauma, congestion or any other cause. Although shown as peripheral, the lesion may be central in location and psychic or organic in character. The sensory nerve connecting the point, P, with the optic thalamus, A, has its negative pole at the irritation-point, P, and its positive in the thalamus. The impulse originating at the point of the lesion, P, may reach the thalamus by an extension of neurones with stations in the nucleus of the column of Goll, or that of the column of Burdack. The neurone, or nerve pathway, continues more or less in a state of irritability, being polarized and passing sensations from the proximate terminal, P, to the distal terminal, A. Therefore ions, hydrogen and carbon, are dissociated and accumulate at the thalamus or positive terminal, which under normal conditions are neutralized when the neurone is at rest by the negative ions dissociated. The positive ions, and carbon dioxide polarized by induction, attack and impair the insulating myelin, and thus immensely raise the value

of polar potentials. The excited fiber, P A, is reflexly connected with the cortex by the extension fiber, A B, and the latter has its negative pole in the thalamus and its positive in the cortex. This polar arrangement

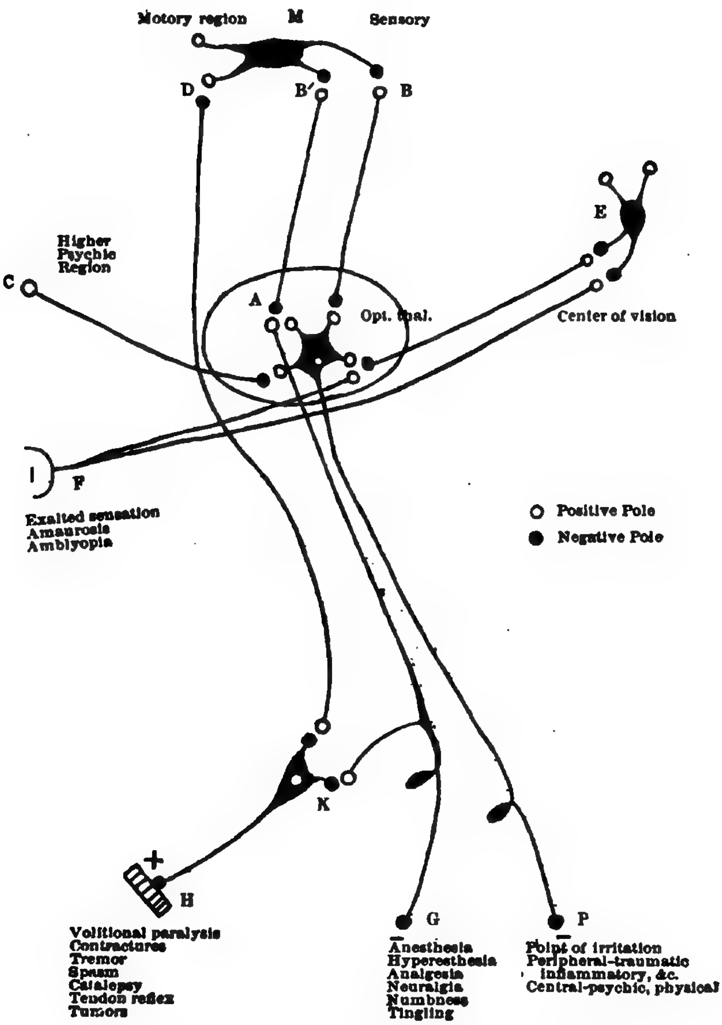


Fig. 125.

Diagram Illustrating Manifestations of Hysteria.

characterizes all afferent neurones, including those of special sense, terminating in the optic thalamus and known as the projection system of fibers. These sensory fibers are numerous, as the thalami are connected with all parts of the cortical area. It is evident that the positive force at the central terminal of the excited neurone, P A, when raised in value by change in the insulation, will influence or even control all approximate negative terminals, which means control of the projection system of fibers. The influence will be normal or physiologically heightened if normal insulation exists, but if that is deficient, neutralization of ions will take place between the positive terminal of the excited fiber, P A, and adjoining negative terminals according to their proximity and lack of insulation. The ganglion, A, thus becomes a fulgurating center, and the condition is propagated through the projection system of fibers.

It is evident that the cortical centers of sensation, vision and the higher psychic faculties, indicated in the diagram, B, E, and C, being connected with the optic thalamus by fibers having their negative poles adjoining the positive of the excited neuromere, P A, and having their negative terminal ions more or less neutralized by the positive ions of the latter, will become secondary explosive centers. Again, from the latter, other centers will become involved, until the whole nervous system becomes engaged in one explosive act, entirely or partially controlled by the primary explosive center in the optic thalamus.

It is clear that the primary explosive force, according to its intensity, will reinforce or annul the normal action of the neurone abnormally influenced by it. Thus the sensory fiber, G A, is reflexly connected with

the cortex by the projection fiber, A B, but if the fiber, A B, is entirely under the primary explosive center, there will be anesthesia at the peripheral point G. If the projection fiber, A B, is only partially under the explosive center, just sufficiently to polarize the fiber, such action will be a reinforcement of a sensation from the periphery, G, and there will be a peripheral hyperesthesia at the point indicated. Analgesia, numbness, neuralgia and tingling at the peripheral point, G, are explained by the varying influence of the explosive center, A, over the projection neurone, A B.

When the cortical sensory centers, B and B′, become explosive they are followed by the cortical cell, M, taking on explosive action. As the latter controls the motor path, D H, the will power is shut off and there exists volitional paralysis of the muscle, H, if the explosive action is sufficient to effect control. Coincident with the volitional paralysis there exists spasm, contracture, or a cataleptic condition, sequences of the explosive action. Tremor is the result of a slight leakage of nerve force.

K represents a cell in the anterior horn of the spinal cord; the arch, indicated by G K H, is not directly affected by the abnormal action, and the tendon reflex may be normal or increased by the general hyperirritability. The optic tract as it extends backward gives off some fibers which terminate in the optic thalamus. The projection fiber, A to E, having its negative pole in the ganglion, will be dominated by the primary explosive center. The center of vision, E, becomes a secondary seat of explosive action; consciousness of light vibrations is therefore shut off, if the explosion is intense. If only a slight normal action exists the sight function will be heightened. As it is with sight

so it is with hearing, taste, and smell; they will be stimulated or annulled, according to the intensity of the leakage acting on the respective centers of these functions.

It is evident that the various periods of hysteria, as well as the prodromes and the individual symptoms, can be accounted for by a variation in the intensity of the vicarious wave-currents resulting from a defective insulation and the factors that govern the directions of these currents. Proximity to the primary explosive center will direct the wave towards a center, but if the irritability of a nerve terminal is lessened by intense action, the direction will be altered to one of a higher excitability. Moreover, any occurrence that attracts the attention of the patient will reinforce the vicarious current and invite it into a different channel. This is the explanation of the symptoms changing under suggestibility. The suggestion directs the mental action toward a certain point, the nerve tract toward that point becomes polarized and the extra current is turned into this tract. It is like levelling a dyke to direct a stream of water. This is in a measure similar to the case of a soldier wounded in battle, when the effects may be delayed until his attention is directed to the fact.

During the period of unconsciousness the whole cerebral cortex is more or less controlled by the misdirected current, which is more or less interrupted, and consequently has been characterized as explosive. Toward the end of this period the muscles, having exhausted their power of contractility, relax. Successive stages are merely manifestations of centers which have maintained their vitality to a greater extent than those more actively involved in the preceding action. Thus the

symptoms change, other neurones become prominent in the act, the manifold manifestations conforming to their varied and distinctive functions, until all are exhausted and there remains the stigmata of the interparoxysmal period. The latter are as varied in character and intensity as the functions of the centers involved, and degrees of vicarious action.

EPILEPSY

296. The immediate cause of epilepsy is an explosion of nerve force. The nervous system is made up of sensory and motor conductors with centers of exchange. When the centers and conductors are at rest they accumulate through nutritional processes a molecular potential. They thus maintain their normal irritability, which under physiologic conditions is never altogether exhausted, the intervals of rest and

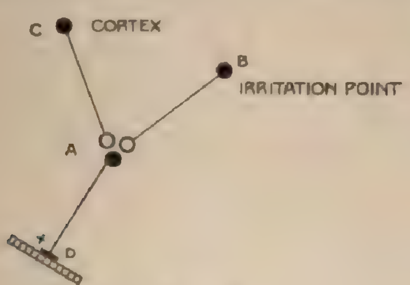


Fig. 126.
O, positive terminal; ●, negative.

action maintaining an equilibrium. The potential is identical in quality with that accumulated in the electric organ of a fish or with the potential of molecules of highly organized tissue in general.

In Fig. 126, A represents a station in the course of a motor pathway. The line, C A, represents a neurone

of the upper segment; D A, a neurone of the lower segment; and B A, a commissural fiber. At the excited terminal, B, there is a lesion which keeps the neurone, B A, in a constant state of excitability. The irritability of the neurone, B A, gives a positive potential to its distal terminal, A, as the initiatory terminal, B, becomes negative. The positive potential being abnormally increased is sedative to the neurone, C A. The sedative action of the positive pole of the neurone, B A, on the adjoining terminal of the neurone, C A, represents the fundamental principle of all sedation. It is the principle of likes repelling likes, or the impenetrability of induced forces to like forces. The repulsion opposes the normal polarization of C A. The converse of this being that unlikes attract, which is the principle of stimulation, and which aids the polarization of opposing terminals, and is the underlying principle of all nerve stimulation. The neurone, D A, may be excited by the neurone, B A, when the latter is abnormally stimulated, or when insulation is impaired, although the neurone, C A, is its normal source of initiatory excitability. The neurone represented by C A continues to receive its full measure of nutrition and its molecular potential is built up to the highest possible degree; the energy in the nutritional storehouses of the neurone is also increased. All of this energy is dammed up by the irritability of B A, as the positive charge of the latter is opposed to the normal polarization of the neurone, C A. Moreover when the energy in the neurone, C A, is stored to such an extent that it begins to boil over (producing the prodromes), ions are dissociated from the constituents of the neurone to such an extent that they displace the sulphur in the neuro-keratin, and the insulation in center, A, is

thus impaired, the specific induction capacity is raised two and a half times (§ 295), the boiling over becomes a flood, explosive centers successively follow each other, and the nervous system becomes engaged in one explosive act. There are three causal factors to the explosion: (1) Storing of energy in the neurone, C A, and its nutritional storehouses; (2) the damming up of this stored energy by the irritability of the neurone, B A; (3) the increase of specific inductive capacity at center, A, by the displacement of sulphur in the insulating neuro-keratin by ions dissociated. The character of the centers affected will determine the character of the epileptic symptoms. All approximating centers and their connections will inductively sympathize more or less. The cortex center, C, becomes a secondary explosive center, successively followed by others. The seat of consciousness is paralyzed by vibrations beyond its measure of appreciation and by inhibitory polarization (§ 265). The various muscles by extraneous stimuli are sent into spasmodic action—tonic or clonic according to their functional condition, the strength of the inducing force, and the approximation of their nerve-centers to the seat of induction. When exhaustion takes place of the molecular potential of the organs engaged in producing the phenomena, depolarization ensues and the patient rests.

Convulsions differ as regards the centers affected and the primary cause. High temperature in a child favors dissociation of the constituents of high potential molecules, and the insulating neuro-keratin is the first to suffer, sulphur being eliminated by destructive metamorphosis. The katabolic process results in an immense increase in *specific inductive capacity* of nerve terminals with consequent explosive action.

Tremor

297. Tremor is an involuntary muscular contraction. It may be divided into two grand classes: (1) A muscular movement of a violent character, with more or less prolonged intervals of relaxation, and epileptic in type; (2) a fine muscular movement, the true tremor, with no distinct period of relaxation. The two varieties may alternate in the same disease, when they are indicative of some cerebral organic lesion.

The true tremor may be confined to the muscles when voluntary movements are taking place, and is then said to be of the intention type, as in disseminated sclerosis; or the tremor may be continuous, that is, occurring when the muscles are at rest; or when they are making a voluntary movement, a condition generally found in paralysis agitans.

Nothing definitely is known of the primary pathologic condition causing tremor. In paralysis agitans and multiple sclerosis the connective tissue in the brain or spinal cord seems to be principally at fault. We have referred to the equilibrium existing between the elastic tissue of nerve or muscular structure, on the one hand, and a tendency to polarization of the nerve or sarcous physiologic elements, termed tonicity, on the other. A disturbance of this equilibrium, such as a lessening of the elasticity of the connective tissue, will allow a partial and intermittent polarization of the nerve or muscular elements, which will constitute a tremulousness—a disturbance in the equipoise of physiologic units. Or, if an increased growth of connective tissue, pressing upon and interfering with the insulating structure separating nerve terminals, allows the escape of nerve force from its accustomed path, such force will cause a

muscular tremor, which will accord in character with the intensity and continuity of the etiological factor. The functional tremors may be accounted for by a slight defect in the insulation of nerve centers situated at a distant point.

Injuries to Nerves

298. Contusions, laceration or puncture will cause neuritis followed by degenerative changes. Hyperesthesia and anesthesia will occur in the course of the nerve. A burning pain is characteristic. Herpetic eruptions and even ulcerations may result. Various trophic changes take place in the parts to which the nerve is distributed. The changes resulting in the nerve itself are peculiar, and are different in the distal and approximate parts. In the distal or peripheral end of a divided nerve degeneration of the fibers commences immediately. From four to six days the white substance of Schwann irregularly segments, undergoes granular degeneration, and finally disappears. The axis cylinder follows by softening and degenerating. Coincident with these changes there is connective tissue proliferation. The fact of degenerative changes primarily affecting the medullary layer is important as showing that insulation suffers before conduction is compromised. These changes extend throughout the whole course of the peripheral end of the injured nerve.

In the central or proximal end of a nerve there are but slight changes after section. A bulbous enlargement is found at the termination, but there are no degenerative changes.

Regeneration takes place, according to the accepted theory, by the new fibers developing from the nuclei of

the neurilemma, the repair proceeding from the periphery to the center.

When the neurilemma proliferates it produces fibrous tissue, and it is improbable that under normal conditions it has the property of producing a higher form of cell. It is conceivable that with specific modifications of pressure, temperature and nutrition the neurilemma may acquire the capacity of producing a nerve-cell or unit, but there is no evidence of such modifications. There are at hand under normal blood-conditions a bountiful supply of physiologic units in the elements of the cytoplasm of leucocytes, or perhaps as unit bases in the globulins, which are capable of being planted as nerve-units. When the normal conditions of nutrition and function are established by connection with the ganglionic cell, these blood-elements may be transformed from conducting elements of amœboid movements to elements having the property of nerve-conductivity. The blood-elements may be fixed in their individual stations by receiving molecules of nutrition from the ganglionic cell. The nutrition furnished will pass along the neurone independently of the presence of nervous conducting elements, and fix the elements of repair at the distal end of the regenerating neurone.

Shock

299. When an energetic stimulus is applied to the nervous system, it may be conveyed to the vital centers with such force as to depress or even to suspend all function. The stimulus may be transmitted through the emotional centers, or through the peripheral sensory nerves, or the sympathetic system. The degree of shock varies with the severity of the injury, its situa-

tion, and the susceptibility of the nervous system of the individual. Expectation of the injury will add to the intensity of the shock; on the contrary, if the mind is keenly engaged otherwise, as in battle, the tension will shut off conduction from the injured part, and the effects of the shock will be postponed.

Shock may be immediate in its effects, causing reflex inhibition of the heart; or if the cause is prolonged suffering or injury, or a protracted surgical operation, the effect may be more gradual in its onset. When the injury or operation is associated with loss of blood shock may follow, the patient lying unconscious with feeble respiration and pulse, with cold extremities and clammy perspiration.

The post-mortem evidences show that the nervous system had lost control over the vascular, resulting in the engorgement of various organs. The minute pathologic conditions attending shock have not been demonstrated.

If it is considered that the molecule of the conducting fiber of nerve tissue has a high potential, both in regard to the number of atoms and their quality—in the aggregate they are electro-chemically negative, and consist of several thousand atoms—it will be seen that the tension is great within the molecule. In fact the atomic tension is so great that the various vibrations of light, sound, taste, touch, or mental stimuli in part decompose the molecule, that is, nerve action produces waste. It is conceivable that such a molecule will be more or less shattered or disintegrated by a violent stimulus; being modified in its atomic construction and reduced in potential by an abrupt dissociation, its conducting properties are interfered with. Moreover, the disintegrants from the action of the vibratory blow may

clog physiologic action, until eliminated, and this inhibition may be the cause of death. What takes place by shock of the nerve conductor is analogous to the results of electrolysis. Even when the shock is slight it takes some time for the molecule to regain its potential and its properties by means of nutrition. The action of shock is the same in character as physiologic action, the difference is in the intensity. The following definition is formulated: *Shock is a shattering, by a vibratory blow, of the nerve molecule or unit, and partial dissociation of its atoms, beyond the immediate recovery of its equipoise.*

Diabetes

300. To differentiate the factors of causality and to pathogenetically classify the varieties of diabetes mellitus, it is necessary to follow the course of sugar through the system from its ingestion to its elimination; and to base the classification upon the points in its course where a departure from physiologic action takes place. The classification is as follows:

1. Diabetes depending on an abnormal quantity of sugar ingested.

2. Diabetes depending on the metabolism of sugar in the liver:

(*a*) On pathological changes influencing the conversion of glucose into glycogen.

(*b*) On pathological changes influencing the conversion of glycogen into glucose.

3. Diabetes depending on the metabolism of the normal amount of glucose furnished by the liver to the blood.

Although the carbohydrates form the larger part of an ordinary diet, obviously an excess can be taken above the capacity of physiologic consumption; and as the urinary organs are the pathway of elimination glycosuria follows. This form has been termed alimentary glycosuria. It is caused by excesses of eating and drinking combined with physical inactivity. It is a mild form of the disorder, and is found usually in obese subjects.

If the glucose in the portal circulation absorbed from the alimentary canal during digestion, is not converted into glycogen and stored in the liver, diabetes follows. Interference with the glycogenic function of the liver may be caused as follows: Puncture of the floor of fourth ventricle, division of the vaso-motor nerves of the liver, or removal of the cervical ganglia of the sympathetic. These evidently by interfering with the hepatic circulation allow the glucose to pass through without being dehydrated. The pancreas has a specialized internal secretion, which contains a glycolytic enzyme according to Lepine. It is probably similar to the product of other glands (§ 203) in that it is a modification of certain blood elements which have been raised in potential as they pass through the gland. It is thus capable when in contact with glucose of dehydrating the latter by chemic reaction, thus forming glycogen molecules, of less potential and less solubility.

The blood which leaves the pancreas passes through the splenic and superior mesenteric veins into the vena portæ which enters the liver and ramifies through its substance. The three essential factors in the glycogenic function are: The dextrose in the blood of the portal system, from the digestive organs; the pancreatic internal secretion from the blood of the pancreatic

veins; and the liver. The latter is the storehouse. The anatomical arrangement is seen to be favorable to the physiologic action. The blood from the pancreas is intimately mixed with the blood from the digestive organs, a chemic reaction takes place between them, and glycogen is precipitated and deposited in the liver. It is clear that a disturbance of the hepatic and perhaps of the pancreatic circulation as that produced by dividing the sympathetic will allow the glucose to pass through the liver, and that disease of the pancreas may affect the secretion of that organ so that it is incapable of dehydrating the glucose.

The stored glycogen in the liver is gradually converted into dextrose. This must take place under direct supervision of the central nervous system through the trophic nerves. These nerves, terminating in contact with the gland-cells, produce polarization of the hepatic elements with the production of ions (§ 203). Ions—hydrogen and oxygen—are impressed into the molecules of glycogen, and the resulting glucose is taken up by the blood. In health this process goes on gradually and constantly, and the production of sugar in the liver is equal to its consumption in the nerves and muscles. Clearly a superirritability of the nervous system will increase the production of sugar as long as there is stored glycogen, and the equilibrium between its production and consumption will be disturbed, with consequent intermittent glycosuria. The ions produced by nerve action being hydrogen, carbon, and oxygen, they evidently unite to form carbon dioxide and water. Osmotic division takes place according to the polarity of the gland, and electro-positive elements go inward with the circulation and electro-negative outward with the secretion. Glucose—water and

glycogen—are found in the blood and carbon dioxide in the bile.

The liver is a depot for stored glycogen. The glycogen is raised in potential by nerve action, and the resulting glucose becomes an element of combustibility in the blood. The glycogen is electro-positive, the glucose is potentially greater in its positive quality. The blood as it passes through the lung increases its free (or loosely held) oxygen, which is electro-negative. There is thus stored in the blood all the elements of combustion.

Although the blood contains the essential elements of combustion, evidently but slight chemical action takes place within the arteries, otherwise the arterial blood would lose its distinctive color. It is probable that the lessened temperature of the blood as it passes through the lung and the resistance to heat radiation are the main factors that prevent chemical reaction taking place between oxygen and glucose within the arterial circulation. The sugar molecule is electro-positive; it may, however, carry within its induced field free oxygen, and consequently within the radius of the glucose molecule, including its induced field, there exists all the elements of combustion, ready to unite under proper conditions, and set free energy. The essential conditions are found under the increased temperature of muscles and nerves, and when the resistance is lessened by nerve and muscle-action as above explained (§ 160). The glucose molecule has a potential equal to about that of four molecules of oxygen, and this represents its value as a potential-carrier. The complete combustion calls for two more molecules of oxygen, which are supplied by potential-tenders.

After a period of activity the muscle or nerve-cell is lowered in potential, that is, there have been dissociated from the physiologic unit a number of its atoms. The dissociation lessens the tension within the unit and lessens the resistance to the escape of energy stored in blood-elements within the nerve and muscle-structures. The increased temperature following the union of the ions dissociated, or the lessened intrinsic tension of the unit, allows combustion of the glucose, and the resulting molecules of hydrogen carbonate are impressed into the physiologic units.

Physiologic investigators have found glycogen stored in the muscles and in different cells. In this case the glycogen may be converted into glucose by ions produced by cell-action, as in the liver, then converted by the oxygen of blood to carbon dioxide and water or hydrogen carbonate; or the glycogen may be directly converted into hydrogen carbonate.

It is clear that an abnormally low muscular or nerve action may prevent oxidation of the glucose of the blood, thus causing diabetes.

Fibroid Tumors of the Uterus

301. Fibroid tumors of the uterus consist of connective and unstriped muscular tissue. They are called fibroma, myoma, or fibromyoma, according to the tissue predominating. They grow from the middle uterine wall, are benign in character, and do not infiltrate surrounding tissue nor infect the general system. They vary in consistence from the firm, hard nodules of fibroid tissue to the soft myoma, and in size from a nodule in the uterine wall to a tumor of over a hundred pounds weight. They are usually found in the

body, rarely in the cervix. Fibroid tumors grow in the direction of least resistance, and are therefore intramural, submucous, or subperitoneal. When many matrices permeate the uterine wall, so as to produce a symmetrically enlarged uterus, they are called interstitial.

Fibroid tumors may be wholly within the pelvic cavity or may become abdominal in situation. They may take on fatty, cystic, calcareous, cancerous or other degenerative processes. They may become inflammatory and suppurate. At the menopause the growth of the neoplasm is arrested usually, but the physiologic change may be delayed beyond the normal time on account of the tumor.

An important electro-therapeutic consideration is the nature and origin of the cells of fibroid tumors. They spring from the fibrous and muscular elements of the uterus, and are modifications of normal cells in development—a modification in vital and functional potential—brought about by the altered nutrition of uterine structure, and altered conditions of pressure whereby normal cells retrograde to the embryonic. There is no need of supposing a pre-existing matrix of embryonic cells as Cohnheim advocated in his hypothesis. There is plenty of evidence of retrogression, progression or alteration of cell-character in the animal and vegetable kingdoms to account for the change in the cells. The normal cells acquire the property of reproduction by a series of changes initiated probably as alterations in circulatory pressure and ending by modification of cell-nutrition. Accompanying the advent of the neoplasm there is weakening of the remaining normal cells, and a lessening of their power of resistance to the encroachment of neoplastic growth.

Nutrition is essential to the functional activity of all cells. It is obvious that in order that a cell-molecule shall gain in potential energy the nutritional elements must be qualitatively the same in potential as the cell. It has been shown that the activity of most cells is accompanied by conversion of molecules into ions. This rule does not apply to all cells: It is evident that a cell which reproduces itself requires different nutrition from a cell which functionates and gives off a limited number of its constituent elements as waste. This leads us to a conception of a classification of cells or cell-units on the basis of the character of their nutrition. The classification is formulated as follows:

1. Cells or units that are surrounded by elements such as proteids, hydro-carbons, etc., which by combustion furnish molecules of nutrition which are converted by the functionating cell or unit into ions. Specifically the molecules of nutrition are hydrogen carbonate, and the ions hydrogen, carbon, and oxygen. Such cells do not multiply but retain a stable base. They are the cell-molecules of muscles, nerves, glands, electric organs, most nucleoli, and the units of the cytoplasm.

2. Cells that are placed in the midst of ions produced by other cells, are built up to a high negative potential, are shut off from blood elements, and are incapable of segmentation, and perform no function under their primary environment. The ova are such cells.

3. Cells that are acted upon by ions, and by secondary ions produced by reactions between the primary ions and the lymph elements, and which have the property of reproduction. To this class belong

the spermatogenetic cells, and probably embryonic cells and cells of tumors.

f. Blood units which pass under the influence of, and are built up by ions furnished by, other units or cells, and pass again into the the circulation, into a secretion, or into cytoplasm. These are potential-carriers, enzymes, etc., of the secretions, and nuclear elements.

The classification might be extended, but the above is sufficient to show that cells being histogenetically related may be transformed from one class to another by means of a change in the nutrition; and that the transformation may be physiologic or pathologic in character. Thus ova by differentiation of environment, and on being supplied by the essential associating molecules of polarization and nutritive elements, acquire reproductive properties; and from the resulting segmenting cells permanent cells of the tissues are planted. Again a simple permanent cell of the serous covering of the ovary is converted into an ovum. The physiologic processes by which these transformations are accomplished are not by changing the fundamental character of the cell, but by a change or changes in its environment and nutritional elements. Furthermore, this rule holds good when the transformation is from a state which is physiologic to one which is pathologic.

The anatomical differentiation as seen in the testicle is a type of the essential conditions of cells that have the property of reproduction; and the osmosis in this structure is such that the lymph elements are acted upon by ions, and the product bathes the segmenting cells. The anatomical arrangement shows that osmosis takes place from the lymph spaces to the tubuli seminiferi. Spermatozoa taken directly from the testis

are quiescent. This is evidently owing to the electro-negative character of the secretion. It is obvious that circulatory pressure must direct osmosis from the lymph spaces toward the tubuli, but the polar differentiation of the endothelial cells bounding the lymph spaces determines the quality of the osmotic flow.

The following changes are submitted as factors in the etiology of the growth of tumors: (1) Continued circulatory modifications which weaken sensitive anatomical elements such as myelin sheaths, elastic fibers, etc. (2) Retardation or blocking of lymphatic streams. (3) Changes in the osmotic flow so that the conditions approach those of the testicular gland.

It is evident that when a cell multiplies the elements added must be the same in character as the constituents of the cell body, *i. e.*, the nutriment of the cell when dividing must contain all the constituent elements of the cell. A cell may be built up by the ions, hydrogen, carbon and oxygen, produced by the action of other cells, but division will not take place. The anatomical structure of the Graafian vesicle supports this conception in the case of the ovum. On the other hand, it is evidenced by the anatomical arrangement of the testicle that these ions acting on lymph-salts and other lymph constituents will furnish the necessary elements for cell division. Similar conditions may exist during embryonal cell-segmentation, although the blastosphere contains all the essential elements. Again it appears that in the repair of tissues, such as in a nerve after its division, the foundation of a cell may be laid by the blood elements—globulins or nucleo-proteids—and subsequently built up by nutrition from the neurone-cell.

The data are not sufficient for positive conclusions being formed on these questions, nevertheless the following formulæ are postulated: (1) Ions produced by cell action will raise the potential of another cell whose base has already been laid, but segmentation will not take place; (2) the ions acting on lymph elements furnish the essential nutriment for cell-segmentation; (3) the blood contains an element which constitutes the foundation of certain cells, but it is modified by nutrition after it is fixed.

302. In pelvic structures during a lengthened period of passive congestion there must be weakening of the more sensitive elements. The lymphatics become clogged, and the osmotic flow may be partially changed. Under these conditions osmosis may pass from the lymph spaces through fibrous and muscular cells to the cavity of the uterus, thus causing endometritis, a symptom more or less pronounced as manifested by serous and other discharges accompanying uterine fibroids.

The part of nerve tissue that is first affected by degeneration is the myelin sheath, thus showing a relative sensitiveness to degenerative changes on the part of structures. It appears that the elastic fibers of muscular sheaths are highly sensitive to circulatory nutritive modifications. The weakening of the elastic fibers impairs the functional activities of muscle-cells. Concurrently changes in the lymphatics seem to occur, as shown by the lymph spaces of Kelb, and the tendency towards the formation of cysts. These changes are significant as indicative of a new relationship of the lymph to adjoining structures. The prominence of the lymph spaces may point to a change in the direction of osmosis. In muscular structure there must be osmosis

from the blood to the muscle and hence to the lymph spaces or veins, and the character of the elements passing towards the muscle must be electro-positive, such as glucose and various proteids to furnish nutrition, and electro-positive salts for associating molecules of polarization. This accords with the osmotic travel to the nucleolus of nerve cells (§ 177).

It is evident that the structure of the pathologic growth is similar to that of the testicle inasmuch as the ions produced by cell-activity act on lymph material, the product reacting on other cells, furnishing nutriment suitable for segmentation and reproduction. The fundamental changes which occur in the transformation of the normal cell of muscular tissue to the pathological cell of the myoma is nutritional in character accomplished by changes in the osmotic flow. The endothelial cells of the lymph spaces occupy a position analogous to the endothelial cells in the testicle, and the muscle and connective tissue cells are acted upon by the products of the action of ions on lymph elements, just as the epithelial cells of the tubuli seminiferi are acted upon. Thus the normal muscle and connective tissue cell acquire new properties, segment and reproduce, and become abnormal cells, the immediate factor in causality of change being an alteration in the nutriion of the cell. Specifically the essential nutrition of a reproductive cell seems to be furnished by secondary ions, the product of the reaction between primary ions and lymph salts; although, as under normal conditions, there are other sources from which the necessary nutrition for reproduction is derived. Just as each molecule has specific potential giving it a distinctive physical character, so the cell-molecule, whether physiologic or pathologic, is distinctive in potential, in

dimensions, and in properties. From a fixed cell such as that of muscle or connective tissue, pathologically endowed with the properties of reproduction, it is but a step in differentiation to the cell of the sarcoma or cancer. A wandering pathologic cell may be planted, nourished and reproduced wherever primary ions are produced in proximation to lymph. Thus along the route of the lymphatics cancer cells flourish. The conception here presents itself that the endothelial layer of cells of the lymphatics may have an important function in the production of ions which physiologically modify the lymph.

Fig. 127
Static Machine (*The Waite & Bartlett Mfg. Co.*)

PART IV

ELECTRO-THERAPEUTICS

CHAPTER XXVII

GENERAL CONSIDERATIONS

303. In the first part of this work electricity (in its broadest sense) is defined as the chemistry of ether. Ether is considered as the simplest form of matter, and the ether molecular state as the zero of force and the standard of neutralization. In its atomic form ether is considered as representing a potential which manifests itself as electricity. Moreover, the potentials of ether-atoms or units are conceived as the common basis of electric, chemic and physical potentials. It must be borne in mind that all force is neutralized—in equilibrium—the difference being in the distance asunder of the potentials (§ 1). Hence a potential force is one capable of actively changing its state of neutralization.

In physiology the differential results of molecular interchange, and the various phenomena of organic matter are conceived as being traceable to properties common to all matter, the chief of which is the *potential of the molecule.* Furthermore it has been shown by experimentations of physiologists, and it might be pre-

dicted without experimentation, that electricity is stimulant or sedative to physiologic action. Still further, as the potentials inherent in the differential ether-atoms are the fundamental units of force, it follows that the action of drugs must have with electricity common units. This allows us to make a generalization of the action of medicinal agents, which is formulated as follows: *The action of medicines depends upon the inherent properties of ether-units within their molecular construction (§ 11, § 155) which are neutralizable by the potentials of physiologic units.*

Fig. 128.

Positive Electric Potential: A type of a molecule of an alkaloidal drug (§ 276, § 277).

Negative Electric Potential: A type of a physiologic unit or molecule (§ 155); or the type of an electro-negative drug-molecule.

It follows that the potentials of drugs differentiate quantitatively and qualitatively; that they may be divided into two great classes qualitatively termed positive and negative; and that the classification of the potentials of molecules as made from chemic and physical manifestations (§ 27, § 32) may be applied to the potentials of drug molecules, and to the reciprocal potentials of physiologic units. Thus there is a differential potential of drugs, and a differential potential of cells or cell-molecules, which by reciprocal action,

either by chemical reaction, physical attraction or repulsion, molecular induction, or vibratile sympathy, produce the complex resultants known as medication.

The following basis for a classification of drugs as they act on the functional activity of tissues or modify vibratory action is formulated:

1. Agents which are stimulant, sedative, or paralysant to nerves by reinforcing, retarding, or counteracting the action of the electro-positive blood-serum on nerve terminals. As types of these may be mentioned strychnia and ether; digitalis and aconite; chloroform and chloral hydrate, as they differentiate in their action, according to the quality of their molecular potentials and vibratory frequencies, on pneumogastric afferent terminals in the endocardium.

2. Agents which furnish associating molecules of polarization to polarizing tissues, or displace or interfere with those furnished by the blood or plasma. Sodium chloride and other salts having a specific action on the function of tissue belong to this class; also chloroform and ether, whose anesthetic properties can be explained by their interference with the specific action of those salts.

3. Agents which increase or decrease absorption of oxygen by the blood. Strychnia and electricity notably belong to the first element of this class; and chloroform by supplanting oxygen in the induced fields of nutrient molecules belongs to the second element of the class.

The successful electro-therapeutist must understand the fundamental principles of electro-physics. He must also have a knowledge of electro-physiology, and must base his therapeutic applications of electricity on his knowledge of the pathology of diseased tissue.

When a student approaches the labyrinthine web of electro-therapeutic facts, and so-called fundamental principles, he may well despair of being able to unravel it. It is therefore the duty of him who undertakes to teach the therapy of electricity, to reduce, as far as possible, the facts and the principles to their elements in order that they may be easily comprehended and remembered.

The differential action of electricity on the tissues may be stated as follows: Electricity may directly charge the molecule and carry it forward with the current (§ 237); it may move the molecule by induction, as in cataphoresis (§ 59); it may dissociate and inductively polarize the atoms of the molecule by converting them into ions, as in electrolysis (§ 53); it may act by vibratile sympathy on the potentials of the molecule, or directly on the functional vibrations by stimulating the molecular or physiologic unit; by neuro-glandular stimulation ions may be produced which, by altering the pressure within an organ (§ 159, § 208, § 230), may change the product of metabolism from a lower to a higher potential, or change the unit from a degenerative cell to a healthy organism (§ 159, § 208, § 230); as an external stimulus by polarization of the physiologic molecule it may produce functional activity manifested as conductivity or contractility, or it may alter the course of osmosis and change the character of the nutrition of the physiologic unit, thus inhibiting its properties of reproduction.

CHAPTER XXVIII

Galvanic Current

304. The action of electricity on healthy or diseased tissue should be studied first from the results of galvanic applications; knowing the physiologic action and therapeutic uses of this current, it will be easy to understand the differential actions of the faradic current and of static electricity.

The distinctive results produced by galvanization are due to the *continuous* character of the current, which gives it an *electrolytic* and *cataphoretic* action not possessed, to any great degree, by the other forms of electricity. Owing to the galvanic current being continuous it can be measured by the meter, which is essential to its being administered with accuracy. Scientifically-applied currents owe to the galvanometer, more than to any other instrument, the merit of the qualification. The galvanic current can be applied with much larger amperage than any other form of electricity, a fact due to the absence of interruptions, and in using large dosage abrupt modifications must be avoided.

The difference between the poles of the galvanic current is much more pronounced than that between those of the faradic, and in electro-therapy the actions of the galvanic poles exhibit such a marked difference as sometimes to show entirely opposite results.

The *positive* is indicated as the active pole in acute stages when there is congestion, inflammatory effusion and tenderness. It may be used in preparatory work where the main indication is the use of the negative, such as inflammatory action supervening on chronic uterine enlargements and displacements. On bleeding surfaces or vascular engorgements, in profuse non-suppurating mucous discharges, in excessive menstruation, in local nervous hyper-excitability it is decidedly indicated. It may be used for its germicidal action, especially when combined with metallic electrolysis.

The *negative* pole, by its diffusibility (§ 28, § 33) and by its electrolytic alkaline reaction, softens inflammatory exudation, glandular or other indurations, even scar tissue being relaxed. It is destructive to hair, moles or growths that are non-vascular. By its increasing the vascularity of the part, it stimulates local nutrition, and promotes healing of ulcerations. It is useful in scanty menstruation or where the menses are absent; and in atrophy or super-involutions of the uterus. It has the power of relaxing mucous canals, a fact worthy of general recognition in the treatment of cervical stenosis, whether or not accompanied by uterine flexion or a uterus fixed by inflammatory adhesion. In uterine adhesions its dissolving influence will produce good results. Chronic adhesions or indurations, from various causes, in joints, muscles, or tendons, will generally improve under negative electrolysis.

The symptom of pain, without taking into account the pathological condition which is its cause, will not determine the selection of the polarity. Pains are sometimes relieved by positive and sometimes by negative applications, and the indications are based more upon the vascularity, the local irritability, and the

acute or chronic stage of the disease, than upon the presence of pain.

In making general and external applications of the galvanic current, the positions of the poles are of equal importance as when the active pole is applied internally. The course of nerve and arterial distribution indicates the position of the electrode in such cases. If the positive electrode is placed in the more central and the negative in a peripheral position, as on one of the extremities, the processes of the circulatory apparatus and the cerebro-spinal and sympathetic nervous system will be stimulated and re-enforced; an exhausted brain will recuperate, sleep will be induced, and mental vigor regained; the circulation will be equalized and congestion lessened; and pains depending on the disturbance of vaso-motor equilibrium, or on an unbalancing of the cerebro-spinal nervous system will be relieved by the sedative tonic action of the positive pole.

305. The following tabulation showing polar differentiation will assist in comprehending this important factor in galvanic therapeutics:

GALVANIC POLAR DIFFERENTIATION

Battery

\+ + + + + + + + + + + + — — — — — — — — — — — —

+		|
Positive pole, +	*Interpolar space*	*Negative pole*, —
Anode		Cathode

Electrolysis

Chemic Dissociation Followed by Electric Induction

Anions.	Cations.
Acids.	Alkalies.
Diffusion of positive and attraction of negative elements.	Diffusion of negative and attraction of positive elements.

Examples

Chlorine	H Cl	Hydrogen

Cataphoresis

Electric Induction Without Chemic Dissociation

Diffusion of soluble elements of positive potential.	Diffusion of soluble elements of negative potential.
Attraction of soluble elements of negative potential.	Attraction of soluble elements of positive potential.

Examples

Diffusion of cocaine; Water.	Diffusion of iodine; Carbon dioxide.

Transference by Direct Electrification

Electrification of the negative part of the molecule, and the molecule carried to point of neutralization.	Electrification of the positive part of the molecule, and the molecule carried to point of neutralization.
Attraction of negative electrifications.	Attraction of positive electrifications.
Desiccating.	Moistening.

Examples

Positive electrification of molecules and their movement toward the negative, as in the first part of electrolysis.	Negative electrification of the bases of salts and their movement toward the positive pole.

Cataphoresis of Nascent Salts

Electrolytic, Chemic, and Cataphoretic Action

Diffusion of nascent salts of positive potential.	Diffusion of nascent salts of negative potential.

Examples

Diffusion of metallic oxy-chlorides.	Diffusion of iodine united with bases of less potential.

Blood Electrification

Polarization of Elements

Small, hard, dark clot.	Large, soft, yellowish clot.

Electrotonus

Anelectrotonus.	Catelectrotonus.
Sedative when potential is kinetic (galvanic).	Stimulating when potential is kinetic (galvanic).
Stimulating when potential is static (static electricity and chemic potentials).	Sedative when potential is static (static electricity and chemic potentials).

Contraction of Muscle

Requires more amperage to contract on closing.	Requires less amperage to contract on closing.
Requires less amperage to contract on opening.	Requires more amperage to contract on opening.

Cataphoretic Action on Cells, Etc.

By direct electrification of movable cells strong currents carry them toward the negative poles.	Direct electrification does not affect position of the cell owing to cell negativity (§ 61, § 353).
By induction weak currents carry them toward the positive pole (§ 237.)	By induction the cell seeks the positive pole.
Proteids, hydrocarbons, etc., by induction, seek the negative pole.	Cellular negative elements, by induction, seek the positive pole.

Therapeutical Considerations

Germicidal.	No germicidal effect.
Drying.	Moistening.
Depleting.	Congesting.
Contracting.	Dilating.
Coagulating.	Liquefying.
Hemostatic.	Increases hemorrhage.
Denutritive.	Promotes local nutrition.
Lessens œdema and inflammation.	Increases local vascularity.
Hardens.	Softens and absorbs.
Lessens mucous secretion.	Increases mucous secretion.

Hinders dilation.	Dilates mucous canals.
Not so destructive.	Destroys and eliminates.
Lessens menstruation.	Promotes menstruation.
Allays hyper-excitability.	Increases irritability.
Indicated in acute conditions.	Indicated in chronic conditions.
Relieves pain in acute or hyperæmic cases.	Relieves pain in chronic or anæmic cases.

INHERENT PROPERTIES

The positive current possesses the property of concentrativeness.	The negative current possesses the property of diffusibility (§ 167, § 39).

The above table shows that the galvanic current covers a large field. It can be made to serve the therapeutic purpose of many drugs. This will be easily understood when the relation of drug and electric potentials is kept in view (§ 303). Unlike drugs, however, electricity does not constitute a foreign substance in the system, but is nevertheless a reinforcement of physiologic processes, be they atomic, molecular, cellular, glandular, absorptive, assimilative or eliminative. The action of electricity when properly applied is the bracing up of the muscular, vaso-motor and cerebro-spinal physiologic action; and owing to its relation to the vital forces, and to its general diffused action, the danger of habit as in the case of the administration of drugs is entirely eliminated from consideration.

CHAPTER XXIX

Faradic Current

306. The secondary coil of a faradic apparatus is within the induction-field of an electric potential existing in the primary or galvanic coil. Like every other induced electric, magnetic, or molecular field this potential records the interruptions, variations, gross or delicate modifications, of the potential that induced it. The modification of the primary potential may be a complete interruption or return to zero, or it may be vibrations of less than a trillionth part of an inch, such as constitute ultra-violet light, each and every one being faithfully and correctly portrayed throughout the induced electric field.

The extreme vibratile sensitiveness of an induced electric or magnetic field, whether the primary potential exists as electric or chemic energy, is of the utmost importance in considering vibratile transmission by nerve tissue § 22, § 67).

It should be borne in mind that in making faradic applications to the human body, that the portion within the circuit constitutes an induced electric field, and that the tissues respond to the various modifications of the primary potential in a degree which accords with their vibratile sensitiveness and the concentration of the current. The vibratile sensitiveness of tissues depends upon their molecular potential and their relative

molecular adjustment (§269, § 174, § 353)—vibratory balance.

The faradic current has comparatively slight polar differentiation. However, the positive pole is the more sedative, and the negative the more stimulating, the latter being sharper and having more effect on nerve and muscle. The shorter and thicker the coil the more marked the polar difference. The faradic current has small electrolytic power. This may be owing to ions not appearing at the electrode, which is not absolute proof that ions are not produced. If it is considered that each molecule is an electrolyte and that when it bends—polarizes—under the influence of the current ions may be dissociated, which the immediate depolarization prevents reaching the electrodes, it is clear that the electrolytic power of the faradic current, like the galvanic, is to be measured by its energy and the molecular character of the substance of the electrolyte.

The cataphoretic action of induced currents must be extremely slight, each interruption bringing back to its original physical position a substance capable of cataphoresis.

The electrotonic effect of the faradic current is considered comparatively small owing to the interruptions, to the small amperage, and to the absence of cataphoretic results. Nevertheless the influence of high-tension currents with high vibratile frequencies have a remarkable power over nerve tissue.

The character of a faradic current is modified by three important factors:

1. The length of the secondary coil giving current-pressure.

2. The thickness of the wire giving current-quantity.

3. The vibratile frequency of the interrupter.

The conventional terms *current of tension* and *current of quantity* have already been defined (§ 85).

307. FARADIC DIFFERENTIATION

CURRENT OF QUANTITY	CURRENT OF TENSION
PHYSICAL CHARACTER	
Short thick wire, No. 18 or 22.	Long thin wire, No. 32 or 36.
Few turns in coil.	Many turns in coil — 15,000 windings.
Low pressure—small e. m. f.	High pressure—great e. m. f.
Slight resistance and slight power to overcome resistance.	Great resistance and great power to overcome resistance.
Low tension.	High tension.
Large volume or amperage.	Small volume or amperage.
Will not glow a Geissler tube.	Requires 4,000 feet of No. 32 or 36 wire to create sufficient tension to glow tube.
Burns iron and steel.	Will not burn iron or steel.
Electroplates in a superior degree.	Electroplates.
EXTERNAL APPLICATIONS	
Owing to cutaneous resistance, currents of quantity have slight effects, increasing as tension is increased.	With a constant primary e. m. f. the effects increase with the length of coil until a maximum is reached, when they decrease with a further increase of length.
Slight action on muscles or sensory nerves.	Maximum power to contract muscular tissue.
INTERNAL APPLICATIONS	
Monopolar or	*Bipolar Methods*
Effects increase with the length of coil until a maximum is reached, when they decrease.	Effects not so pronounced as from the current of quantity.
Pronounced effects on pelvic organs; contracts uterus, rectum etc., even to a painful degree.	Sedative to internal organs, relieves pelvic pain and hyperesthetic conditions.

Indicated in post-partum hemorrhage, is superior to ergot; in subinvolution without tenderness; in relaxation of muscular tissue without inflammatory conditions.

Indicated in painful or sensitive conditions when cause is situated in pelvic nerves; in post-operative neuralgias where the primary cause has been removed. In passive congestions accompanied with pain.

General Applications

Short coarse coils, coarse vibrations, give a current having merely muscular effects.

Long coil, 7,000 feet, and rapid smooth vibrations furnish a current pre-eminently a constitutional tonic. Can be applied to the point of endurance without pain. In neurasthenia, nervous breakdown, insomnia and allied nervous ailments this current is incomparable.

308. INTERRUPTION FREQUENCIES

Slow.	*Rapid.*
From a single impulse upwards.	Upwards to 30,000.
Associated with current of quantity or with such tensions as will overcome resistance.	Associated with tension suitable for physiologic or therapeutic purpose.
50 to 100 produce alternate muscular contraction and relaxation.	Above 200 or 300, tetanic contraction.
Do not tire muscle.	Fatigue muscle.
Stimulate nutrition, produce strength and endurance.	Exhaust muscle.
2,000 to 3,000 vibrations employed to break up adhesions and disperse exudates.	Very rapid vibrations relieve pain, are sedative, anti-congestive.
Vigorous electro-muscular massage.	Antispasmodic.

From 1 to 6,000 vibrations, muscular effects chiefly experienced.

Upwards to 18,000, muscular response gives way to nerve stimulation.

From 18,000 upwards, muscular and nerve effects lost, and cutaneous anesthesia ensues.

The above tabulation is sufficiently elaborate to show that there are three important factors in determining the character of the faradic current: (1) Length of the coil, pressure or e. m. f.; (2) thickness of the wire, or volume; and (3) frequency of the interruptions. The operator therefore has to use judgment in making combinations. A modern faradic apparatus should give several currents, each having distinctive physical, physiologic and therapeutic effects, produced by combinations of length and thickness of wire, and frequency of vibrations.

309. When the interruptions are slow—up to 100 a minute—the muscles have an interval of rest between contractions and there is no pain nor fatigue. With a rapidity of 200 or 300 per minute, there being no relaxation, the fatigue, distress or even pain will soon become intolerable. With a proper regulation of the current the nutrition, and therefore the strength and endurance of the muscle are maintained.

When the interruptions are frequent—10,000 to 20,000—and with a dosage not sufficient to produce tetanic contractions, muscular fatigue and distress will be removed, congestion relieved, and nutrition stimulated.

It is found that non-striated muscles do not contract under the current from a thick, short coil, slowly interrupted. On the other hand a current of tension with rapid vibration will contract involuntary muscles, causing intestinal peristalsis, constriction of small blood vessels and other physiologic effects.

In uterine adhesions, when the galvanic current has done its electrolytic work, and when there is an entire absence of acute inflammatory action, the faradic current of decided volume and with interruptions ranging

from 200 up to 1,000 per minute, will be found useful in breaking them up. A current of high tension and very rapid vibration can be employed to allay the distress set up by the muscle stimulation.

High tension rapidly interrupted faradic currents, running in a perfectly smooth manner, produce remarkable effects on the tissues, probably due to vibratile molecular effects. They soothe and stimulate the functional activity of the nerves, contract the arteries thus regulating the circulation, and promoting sleep and rest. The effect on metabolism is thus direct and indirect. These currents are useful in assisting the electrolytic work of the galvanic, in promoting absorption, in allaying irritation, in correcting inflammatory tendencies, and, in general, preparing the patient's condition for the next galvanic seance.

A surgical operation is often consented to because of the attending symptoms of pain and distress, and too frequently these symptoms remain after the operation. Under these circumstances the induced current of high tention is a valuable auxiliary not often taken advantage of. By stimulating the lymphatics it will promote absorptions of residual exudation; as a vaso-motor constrictor it will regulate the circulation; and as a nerve sedative it allays the remaining hyperirritability. It is anti-spasmodic and anti-congestive, and by producing local anesthesia it allows recuperative rest. As a sleep producer its general application is not excelled by any other agent.

In general it may be said that the induced currents of high tension always assist physiologic action. They increase the strength and vitality, and the desire to work. They stimulate the appetite, aid the digestion and promote assimilation. It has been found that in

rheumatism, gout, and diabetes they increase the elimination of urea.

The negative pole of the faradic battery is more stimulating than the positive, and it is the break or depolarizing current that is considered in designating the poles or direction of current (§ 86).

310. THE GALVANIC AND FARADIC CURRENTS COMPARED

GALVANIC CURRENT	FARADIC CURRENT
ELECTRO-PHYSICS	
Great polar differentiation.	Slight polar differentiation.
Great electrolytic power corresponding to energy-value.	Slight manifestation at electrodes, but electrolysis must be directly proportional to energy.
Powerful cataphoretic action.	Slight, if any, cataphoretic action.
Deflects galvanometer needle.	Cannot deflect needle because of mechanical impossibility.
Produces spark.	Produces spark.
Transformed into heat.	Transformed into heat.
Obeys Ohm's Law.	Obeys Ohm's law.
ELECTRO-PHYSIOLOGY	
Electrotonus great.	Electrotonus in a less degree.
Distinct anelectrotonus and catelectrotonus.	Distinction between poles not so great
Skin: Burning.	Skin: Stinging and pricking.
Muscle: Contraction when current modified.	Contraction, beacause each make and break is a modification of current.
Blood vessels: Contraction.	Blood vessels: Contraction slower.
Nerves: Prickling, tingling and numbness	Same as galvanic.
Blood: Coagulates.	Coagulates very feebly.
Nutrition: Powerful effect chiefly through nervous system.	Powerful effect chiefly through muscular contraction.

Electro-therapy

Paralyzed muscles: Contraction after they fail to respond to faradic current.	Contraction, but fails with advanced degeneration.
Neuralgias. Relieves by electrotonus and by regulating circulation.	Relieves by rapid vibration.
Secretion. Stimulates and absorbs by electrolysis and cataphoresis.	Stimulates and absorbs through nervous and muscular action.
Tumors: Absorbs by electrolysis.	Absorbs by stimulating nervous and muscular tissue.
Ulcers: Heals.	Has less influence.

Current Advantages

GALVANIC	FARADIC
Possesses greater amperage and overcomes resistances of internal organs.	More easily applied so as to produce muscular contraction. In general applications innumerable contractions produced by passing electrode over surface. This advantage is not so marked in local applications.
Produces muscular contractions in paralysis when faradic fails.	Greater mechanical effect—electro-massage.
Has more powerful electrolytic, cataphoretic, electrotonic, and thermic action.	Less likely to produce harmful results. Seances can be repeated oftener. In application to head, spine, etc., galvanic seance cannot be prolonged, but faradization can be prolonged and repeated with benefit to the patient.

All electric manifestations are based on the potential-units of free ether atoms. Galvanic, faradic, and static electricity are modifications of the same force, differing in their mode of production, and their method and medium of circulation. In their physical, physiologic

and therapeutic effects the difference is one of degree and not of kind. However, in the complex reciprocal reactions that take place between organic tissues and the various currents, in their numerous methods of administration, the difference in the results is so great as to amount practically to a difference of kind. There is but one division of electricity that is based on a difference of kind, that is a division made on the differential fundamental characters of the positive and negative ether atoms. These differential properties have not been fully investigated, but that the positive has comparatively a greater degree of concentrativeness, and the negative a comparatively greater degree of diffusibility, experimentations have made clear (§ 28, § 33).

CHAPTER XXX

Franklinic or Static Electricity

311. By static electricity is meant dissociated ether atoms in equilibrium. When the galvanic or faradic current is applied to the body the interpolar portion only is affected by the application. With static electricity an insulated electric lake is created into which the patient is immersed, causing a complete general electrification. This electrification may consist either of positive or negative ether atoms, the opposite electrification being on the surrounding proximate conductors, earth, walls, gas pipes, electrodes, etc. The patient therefore constitutes one large electrode positive or negative according to the charge. Although the general electrification of the patient is static in form, it becomes dynamic in the shape of sparks, breezes, etc., which have all the properties of other currents, being capable of electrolysis and cataphoresis, under favorable conditions. However, the franklinic form of electricity is not used directly for electrolytic or cataphoretic purposes, but for its action on the various functions of the body.

When the patient is placed on the platform of a static apparatus in action he is wholly under the influence of the electric charge. Every molecule, cell, fiber, organ, or tissue is influenced by the attractions and repulsions of the static electrification. Owing to the

law of attraction and repulsion (§ 4) and that of potential surfaces (§ 8), the electricity is largely on the surface of the body, but the body-mass of the patient constitutes the induced magnetic field of the electric potential, and parts that are not charged directly are charged inductively (§ 66). Every molecule or cell in the body must therefore be responsive, and each variation that takes place in the electric potential must be duly recorded throughout the body. Every part of the body must be more or less in a condition of tension; every exciting influence, even to a ray of light, that affects the electric primary potential must affect every molecule according to its potential and vibratile sensitiveness.

When the electric potential—the atomic ether-mass—is lessened by the withdrawal of part of it by means of a spray or spark, the agitation throughout the electrification must be complete, not only as regards the direct electric potential but as regards the induced electric field. A partial analogy may be observed by a withdrawal of a bucketful of water from a tank. Each particle of water in the tank is agitated. The fundamental principle underlying all franklinic action is molecular or physiologic vibration or polarization, and this is a fundamental principle of all physiologic action. It follows that static electric applications in proper dosage is a stimulant to all the functions. It tends to adjust the actions of the circulatory, respiratory, nervous, secretory and excretory apparatus, and its mode of action is by polarizing the highly responsive molecules and physiologic units engaged in the various functions. It agitates and readjusts, it promotes oxidization and eliminates, and by clearing the field of the katabolites it allows nutritive elements to be attracted

by the tissues, and renders possible a healthy metabolism and a normal action.

Although the evidence of electrolytic action is not clearly manifested as in galvanic current-application, yet as molecular polarization is the first step to disintegration (§ 42) it is probable that the atoms of high potential molecules are in part dissociated even during simple electrification. When sprays or sparks are applied there is no doubt but that the electrolytic and cataphoretic actions are great. Metabolism is thus stimulated, and the katabolites, the products of a pathologic nervous system, are swept into the eliminating pathways, and the fields cleared for healthy tissue metamorphosis. Thus in neurasthenia, gout, rheumatism and uric acid diathesis, increased elimination, increased tissue-change and increased absorption of oxygen, effected by static application, excel those effected by any other measure of treatment.

In hyperirritability of the nervous system static electricity improves anemic and hyperemic conditions, besides bringing the vibratory properties of the neurones into more uniform action. The hyperirritability is often maintained by the presence of katabolic elements abnormal in amount and kind. When these are eliminated there is a healthy basis for physiologic anabolism.

Static electricity by its action on the nervous system produces functional activity throughout the body. Each neurone, be it afferent or efferent, specialized or common, is excited to its distinctive physiologic action. Sensation, special sensation, motor and glandular action are thus stimulated. Through its action on the sympathetic it produces important vaso-motor changes, determining the amount of blood flow to the various organs. Secretion and excretion are modified quanti-

tatively and qualitatively by the respective stimulation of vaso-motor nerves and the cerebro-spinal system.

Locally franklinic electricity will act as a stimulating massage, promoting absorption, dispersing exudates, lessening œdema, effusions, and thickening of joints. It can be used as a counter-irritant, a sedative or a stimulant, relieving pain and overcoming paralysis.

Static machines have immense electro-motive force, *i. e.*, immense pressure. The potential therefore of an electric charge is immense, and there is a large and intense induced electric field which embraces not only the patient but surrounding area. The molecules in the atmosphere in the neighborhood of the machine or patient are polarized, or possessed by the primary potential, and synchronous with each spark there is an agitative response. The surrounding area bears the same relation to the body-mass of the patient as the area occupied by the secondary coil to the interior of the primary, or to the interior of a solenoid. The atmospheric oscillatory commotion therefore is inductive in character, and the body of the patient is in the most intense part of the induced electric field (§ 66).

312. *Character of Franklinic Currents.* In the disruptive discharges (§ 95) from a static machine in which the positive and negative atoms of ether unite, there is not that continuity of flow that characterizes the galvanic current. It is interrupted or oscillatory, a characteristic which depends on the interrupted induction of the apparatus, and on the fact that electricity travels through air by means of charged particles. These oscillating and quivering loaded particles constitute a real ray of energy (§ 124), are free to choose their path, and are repelled from the surface of the electrodes in an interrupted manner. Each oscillation

and interruption must be propagated throughout the induced electric field. The frequencies of these oscillations have been estimated by thousands or millions, and are capable of infinite variation.

313. *Methods of Application.* When the patient is placed on an insulated platform which is metallicly connected with one of the prime conductors, general electrification ensues. This charge is the foundation step of all methods of static administration.

General electrification constitutes a useful method of treatment. No doubt the particles of air surrounding the body become charged and radiate toward the opposite electrification or pole. This takes place so silently and in such a diffused manner that no manifestation takes place as in the spark. The radiation however produces vibratory effects in the charge and in the induced electric field.

The fundamental action therefore of static electrification, whether positive or negative, is *molecular polarization* and delicate *molecular vibration*, and the other methods—breeze and spark—are only modifications of these in intensity.

The difference between positive and negative electrification is not well defined by operators. To speak of the positive as a high potential pole and of the negative as a low potential pole is entirely misleading, and it is unfortunate that the terms, positive and negative, have been applied to electrification. If any pole deserves to be characterized as positive, as regards effects, it is the so-called negative.

When under the influence of general electrification the patient is slightly conscious of the influence. The feeling is agreeable with a restful composure. There may be a slight diaphoretic action, but the result is

refreshing and tonic. In neurasthenia, convalescence from exhausting diseases, insomnia, nerve-fatigue and different cachexiæ simple electrification is found useful.

Breeze. By this is meant a concentration of the radiations by means of an electrode. The nomenclature used is misleading. When the patient is positively electrified—connected with the primary positive conductor—it is the positive ether that produces the effects whether a spark or a breeze is the method used, and it ought to be characterized as a *positive application*. Instead of this it is termed "*negative breeze*" or "*negative spark*." Also when the patient is subjected to negative electrification it is entirely a *negative application*, and the terms "*positive breeze*" and "*positive spark*" are not applicable. Moreover a spark or a breeze is neither positive nor negative, consisting of both, the illumination in the spark being produced by the neutralization of the positive and negative ether atoms and the subsequent radiation. As union of positive and negative ether takes place in the spark the opposite electrification cannot affect the patient, as it is neutralized before reaching his body. The breeze only differs from the spark in being more diffused and in the production of heat waves instead of light.

Positive electrification with breeze radiations is stimulant and even irritating. It may be used as an excitant to local nutrition, or as a counter-irritant to the cutaneous surface. It may be modified in strength from a gentle current to a strong spray mixed with sparks. The strong breeze is indicated in coldness of the extremities with imperfect circulation, torpor of certain organs, anesthesia, and myalgias, etc.

Negative electrification with breeze radiations is sedative, allays hyperirritability and relieves congestive

headaches. It dries profuse discharges, is antiphlogistic, and relieves heat and itching. It is indicated in insomnia, inducing a restful sleep. It alleviates painful conditions, relieving congestion and hastening resolution.

When the positive pole of the galvanic current is applied to a part it is sedative, drying, and acts in a remarkably similar manner to negative electrification with breeze radiation—the positive breeze of some authors. It appears therefore that positive electricity entering organic tissue as in the galvanic current is comparatively sedative, but on leaving as in the franklinic breeze it is stimulant; on the other hand negative electricity entering an organism as in galvanization is comparatively stimulant, but on leaving as in the franklinic breeze it is sedative. These peculiar manifestations accord with the physiologic order of electromuscular contractions (§ 197).

Cathode closing is the most energetic stimulant to muscular tissue of all modifications of the galvanic current. Cathode closing is negative electricity entering the tissues and has a counterpart in positive exit which takes place with the so-called negative spray or spark, which correctly speaking is positive electrification with spray or spark radiations.

Cataphoretically and electrolytically it will be found that positive exit has all the qualities and properties of negative entrance, and that water without chemic dissociation, and cations are carried by positive electrification toward the exit point.

Authors speak of positive electrification as a high potential charge and of negative electrification as a low potential charge. This is absolutely incorrect and misleading. The charges are equal in potential, and when

union takes place completely neutralize each other. The low point is zero, on either side of which is a potential absolutely equal. Each of the ether atoms is a positive entity quantitatively equal in properties but differing qualitatively. Owing to this difference of quality the positive entity is more positive in action under certain conditions, and the negative entity under other conditions is more positive in character.

The relative position of an organ in the electric path is of equal importance to the quality of the current. In the measurement of currents by the galvanometer it is found that there is an equal amount in all parts of the circuit, that is, the sum of the attractions and repulsions is the same independently of the quality of the current. If positive ether is passing a given point it will influence the needle in an equal degree and in the same direction as the same amount of negative ether travelling in the *opposite* direction (§ 48). It follows that at the point of exit, as in a spark or breeze, positive electricity is stimulant, whilst at the other parts of the surface where the charge enters it is sedative. At the latter points, however, the electric movements are so diffused as not to be appreciable.

In negative electrification the opposite results are obtained because the *direction* of the negative ether movement is similar to the direction of the movement under positive electrification.

314. *Sparks.* Spark radiations differ from the breeze in being more concentrated. The patient may be electrified positively or negatively as before. Thus there are *positive electrification with spark radiations*, and *negative electrification with spark radiations.* Sparks being more intense than the breeze, the disruption sets up a more extensive and intensive oscillatory agitation in

the electrification and in the induced electric field. Sparks are more stimulating than the breeze, and vary in relative intensity according to the difference of potential and resistance (§ 96). The spark is more energetic than any other form of franklinic discharge. It produces strong muscular contractions and exerts extensive influence over metabolism. In anesthesias and myalgias it excels as a stimulant. Locally it excites paralyzed muscles, softens indurations, stimulates absorption of exudates and breaks up adhesions. It usually prevails over rheumatism, gout, malaria, sciatica and neuralgia. To administer the spark requires skill, and the patient's confidence should be gained before applying it energetically.

Roller Applications—Massage. The intensity of this method depends on the distance between the two sliding poles. On starting, the poles should be comparatively near each other and afterwards gradually drawn apart, thus increasing the electrode-current.

The roller electrode may be connected with either pole and the platform with the other; the selection of the poles being made as in the case of the static breeze. The roller electrode may be used with the Leyden jar current.

Potential-Alternation. To Monell is due the introduction of this method. The patient being charged in the usual manner, the potential is suddenly reduced to zero by the approximation of an interrupter to the conducting rod. A succession of alternations between high potential and zero as rapidly or slowly as desired can be maintained. There is no doubt but this is an effective method of stimulating tissue metamorphosis and aiding nutrition.

Leyden Jar Currents

315. Leyden jars are employed for the purpose of re-enforcing the action of static machines, and they are valuable in this respect when owing to a humid atmosphere the high electro-motive force of the machine cannot be maintained.

Franklinic Induced Current. When a pair of jars are connected with the prime conductors of a static machine and the outer coatings connected by a pair of conducting cords, the inner and outer coatings of the jar will bear the same relationship to each other as the primary and secondary coils of a faradic apparatus. The current furnished by this method is called the static induced current. It is quantitatively regulated by the specific inductive capacity of the jar, by their size and by the pressure—electro-motive force of the static machine. It is qualitatively modified by the interruption—frequency—which depends upon the rate of revolution. The static induction currents correspond in quality to high frequency and high tension faradic currents, but can be made to excel the latter both in tension and frequency of interruption.

The claim has been made that the Leyden jar inductive currents have superior power in relieving pain and contracting muscles, owing to their intense oscillatory character.

The following is a summary of the medical results attained in 1881 by Dr. Wm. Morton, to whom just credit is given for priority in production and use of the franklinic induced current: *

* Report of Special Committee, appointed at the Tenth Annual Meeting of the American Electro-Therapeutic Association, September 27, 1900.

"*1*. By means of the spark-gap at the discharging rod the perceptible effect may be regulated to a nicety, from an almost imperceptible tingle up to extreme and rigid flexion of the arms.

"*2*. The effect is soft and agreeable and accompanied by no shock, while the inner coating of the jars gives a series of discharges which, even when slight, are too painful to be borne.

"*3*. Capable of causing physiological tetanus, while a connection between the inner coatings of the jars in silent current forms produces no muscular contractions or sensations of any kind.

"*4*. When compared with the galvano- or magneto-induced current produces more efficient contractions and gives less pain to the patient, where pain would be produced by any of the three.

"*5*. Renders a static machine capable of producing all the effects of faradism, doing all the work of the best faradic machines, in addition to the ordinary static effects. In its general characteristics this current cannot be distinguished from the ordinary faradic current."

CHAPTER XXXI

The Sinusoidal Alternating Magneto-Electric Current

316. It is claimed that this current produces physiologic effects characterized by painlessness, and comparatively great penetrating power. D'Arsonval showed that the sensory and motor effects were in direct proportion to the variation of potential at the point excited. Kellogg described the effects produced by a sinusoidal current from an apparatus designed by himself as follows:*

"When rotated slowly and connected with sponge electrodes, held one in each hand, vigorous contractions are produced in each arm, and in alternation, nearly all the muscles of the arm seeming to participate in the contractions. When one electrode is placed in contact with the feet and the other held between the two hands, the muscles of both extremities are made to contract vigorously. The contraction is spasmodic rather than tetanic in character. By proper adjustment of the current, strong muscular contractions may be induced without the slightest sensation in the skin, and without any painful sensation whatever. With one electrode placed in the rectum or the vagina, and the other upon the abdomen, strong contractions of the

* International System of Electro-Therapeutics.

abdominal muscles, and even of the muscles of the upper thigh, may be produced without any sensation other than that of motion. I have frequently seen patients, while taking this current, shaking so vigorously under its influence that the office table was made to tremble quite violently with the movement.

"With rapid rotation of the machine, the current obtained is capable of producing strong tetanic contractions similar to those of the faradic machine. The only skin sensation produced by an application, sufficiently strong to induce tetanic contractions, is a slight prickling, very much less intense than that produced by a faradic current capable of exciting equally strong motor effects.

"The sensory effects produced by the current are exceedingly interesting. As has already been stated, applications of the current sufficiently strong to produce vigorous muscular contractions are attended by no sensory effects whatever. The sensory effects are best obtained by giving the machine a high velocity. Adjusting the apparatus for high velocity, and applying the sponge electrodes, well moistened, to the temples, with a gradually increasing current and with the eyes closed, one seems to see rotating waves of light resembling a luminous whirlpool in the region of each electrode, but without other sensation except a metallic taste.

"It is a curious fact that the position of this luminous field is not stationary; it moves with the electrode, which seems to be the center of the illuminated area. As the current is increased in strength the display of light increases in brilliancy, finally becoming so extended and intense that the whole front portion of the head seems to be brightly illuminated. At this point

one begins to experience very slight prickling sensations in the skin, and a peculiar pulling sensation, which increases as the intensity of the current is increased. A remarkable characteristic of the current is, that so strong impressions are made on the optic nerves, or their centers, by a current too delicate to be recognized by the nerves of the skin. This effect must be due to the great penetrability of the current.

"The therapeutic indications for which I have employed the sinusoidal current have been based upon the peculiar motor and sensory effects which I first observed ten years ago, some of which have since been observed and described by d'Arsonval and Apostoli.

"Within the last ten years I have made more than 20,000 applications of the sinusoidal current. Twelve thousand of these applications have been made within the last three years. The greater number of the applications have been made in gynæcological cases, although hundreds of applications have been in cases not belonging to this class."

Great Frequencies of Current-Interruption

317. Professor A. d'Arsonval showed that application of sinusoidal waves of great frequencies does not affect functionally the nerves or muscles, neither pain nor muscular contraction being produced. On the other hand there is an increased metabolism, as shown by the increased absorption of oxygen and the elimination of carbon dioxide.

The muscle becomes tetanized at from twenty to thirty waves per second, and the excitation is intensified in relative proportion up to a maximum, when the effect decreases with additional increase of electric

oscillations. The maximum varies from 2,500 to 5,000 per second. The results show that with sufficiently rapid vibrations, currents may be insensibly passed through the body which would produce fatal effects if the frequencies were lessened.

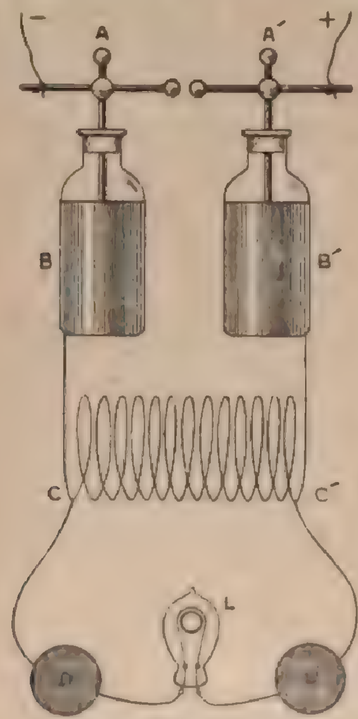


Fig. 129.
Arrangement of Leyden Jars for Producing Alternating Currents of Great Frequency (d'Arsonval-Hertz).

D'Arsonval has succeeded in producing alternations at a rate of 1,000,000,000 per second. The following is taken from an article by d'Arsonval and is translated by J. H. Kellogg:*

"In my recent researches I found great advantage in the exclusive employment of the following apparatus, of which the experiments of M. Lodge have given me many suggestions: Let A A′ (Fig. 128) represent the armatures of two Leyden jars arranged in cascade. The armatures are joined to an electrical apparatus of high potential (as a Holtz machine, Ruhmkorff coil or transformer). The external armatures, B B′, are joined together by a solenoid, C C′, composed of coarse copper wire making fifteen or twenty turns. Each time a spark passes between A A′ an oscillating current of ex-

*International System of Electro-Therapeutics. Bigelow-Massey. Second Edition.

treme energy is produced in the solenoid, so that by connecting its extremities, C C′, a current is produced which may bring to a white light a strong incandescent lamp, L, held between two persons, D D′. The spark which is obtained between C C′ is much longer than that which passes between A A′. This is due to the fact that in the latter case the discharge of the external armature, A A′, is slowly developed, the difference in potential between the poles increasing until the spark passes. In these conditions the position of the solenoid plays a secondary rôle, while its self-induction becomes preponderant. The effect of these sudden discharges is analogous to those facts in mechanics relating to the action of instantaneous forces. A piece of gun-cotton placed upon a piece of steel burns slowly if lighted, but will break the piece if made to explode by means of fulminate of mercury. The same amount of energy, however, has been set free in both cases; but in the second the pressure generated by the gas is so intense that the resistance of air becomes comparable to that of steel. This is the principle illustrated in the difference between the electrical pressure developed gradually in A A′ and, on the contrary, suddenly in C C′ at the moment when the jar is discharged. If it is desired to increase the tension of the current, it is sufficient to introduce into the solenoid a bobbin with a large number of turns. This bobbin is placed in a tube of glass filled with oil, which insulates it completely.

"We may utilize in two different ways the currents thus obtained: First, by passing them directly through the tissues; second, by placing the tissues on the interior of the solenoid without making any communication with it. In the second case the tissues placed in the solenoid are the seat of induction currents of extreme

energy. They act like conductors closed upon them selves, and are traversed by induced currents of great intensity. From a physiological point of view, the effects obtained are the same in the two cases, and are chiefly as follows: First, no effect upon the general sensibility and muscular contractility. This is the most striking phenomenon. We have currents capable of burning to incandescence a series of electrical lamps. These lamps placed between two persons, D D′ (Fig. 128), completing the circuit, are lighted without producing any sensorial impressions. The current is very strong. A little heat may be experienced at the point of entrance and exit of the current from the body. I have been able to pass through my body currents more than 3,000 milliamperes, when currents of a quantity ten times less would be extremely dangerous if the frequency in the place of being 500,000 to 1,000,000 per second were lowered to 100 per second, the usual rate of alternating currents employed for medical purposes. There has been much anxiety for an explanation of these paradoxical results to which I first called attention in my lectures at the College of France and at the Society of Biology. In my communication to the Society of Biology I suggested two hypotheses: 1. Whether these currents, on account of their enormous frequency, pass exclusively upon the surface of the body (it is well known that ordinary currents of great frequency do not penetrate, but flow upon the surface of the conductor, as does static electricity). 2. Whether the sensory and motor nerves are organized to respond only to vibrations of determined frequency, as we see, for example, in the case of the optic nerve, the terminations of which are blind to the undulations of ether at a rate

less than 497 billion (red), and greater than 728 billion per second (violet).

"The acoustic nerve is in the same situation as regards sonorous vibrations. Below and above certain vibratory periods musical sounds no longer exist, and the ear remains insensible to these vibrations. The human body does not behave like a metallic conductor. Currents of great frequency, in the place of flowing on the surface of the body, penetrate into the body and influence nerve-centers deeply situated, both directly and by producing induced currents. Whether these currents are direct or induced, the sum-total of the energy which traverses the body remains the same, and the result is the same in both cases. By employing a current of great frequency, the body is traversed without showing any reaction by currents, the energy of which would destroy it if the frequency were lowered. We can explain this innocuousness by the absence of excitations, or, better still, by supposing that these currents exercise upon nerve-centers and muscles the remarkable special action studied by Brown-Sequard under the name of inhibition. Experiments, in fact, demonstrate in the most striking manner this inhibitory action of currents of great frequency, as we shall now show:

"*1.* The tissues traversed by these currents become rapidly less excitable to ordinary excitants. This diminution shows itself by a remarkable analgesic effect produced at the point where the current penetrates the body. This analgesia persists, according to the case and subject, from one to twenty minutes.

"*2.* The vaso-motor system is powerfully affected. If, for example, the mercurial manometer is placed in the parotid of a dog, the arterial pressure is ob-

served to fall several centimeters under the influence of this form of electrization. We may observe the same phenomena in man by the aid of a sphygmograph. There is then manifest inhibition of the vaso-motor system, aside from all conscious sensation. This fact proves that currents of great frequency penetrate deeply into the body, as I have stated above.

"*3*. Continue the currents a sufficiently long time in man, and the skin becomes reddened and is covered with perspiration,—a natural consequence of the action of the current upon the vaso-motor centers. The same result is obtained by placing the subject upon an insulated stool in communication with one of the poles of the high potential, the second pole being in communication with a metallic plate, supported at a sufficient distance from it. The patient is thus submitted to the action of an oscillating electrical field.

"*4*. By submitting an entire animal to these currents, either directly or by placing it in the solenoid, we may observe an increase in the intensity of the respiratory combustion. The thermometer shows that there is no increase in the internal temperature. The excess of heat produced is lost by radiation and evaporation, as may be observed by placing the animal in one of the calorimeters which I have briefly described.

"*5*. To discern the action of these currents in a living cell I have employed the yeast of beer, and in collaboration with M. Charrin I have studied the bacillus pyocyanic.

"The results which I have briefly indicated, and those already obtained in clinical experiments, give

me hope that we possess, in these various forms of electricity, important therapeutic resources."

Evidently currents of immense frequencies are capable of acting upon nutritional and the simple or small molecules of the tissues, thus producing metabolic changes. At the same time the physiological elements or molecules of nerves and muscles—the sarcomeres and the neuromeres—are incapable of responding to such frequencies. In this respect the nerve and muscular units behave similarly to the galvanometer needle when subjected to a faradic current. The needle rests because mechanically unable to follow the variations of the current (§ 75). Obviously physiologic effects are absent whilst purely chemic effects are present. Hence the potential of the current can be increased indefinitely if oxygen and other essential elements of anabolism are bountifully supplied, so that the natural anabolic process eventually equals current-katabolism. The inhibitory power referred to is explainable on the basis of a greater taking possession of a less force. Currents of high frequency pass through the small molecules of the induced fields of the physiologic units and thus inhibit the function of the latter. For instance, the isotropic substance is in possession of the current, hence the anisotropic molecule is inhibited. It is the same with the nerve elements. Obviously the current initiates reactions between potential-carriers and oxygen in their induced fields, thus making way for other potential-carriers (nutritional elements) and the absorption of more oxygen with increased elimination of carbon dioxide. It is possible that concurrently with the katabolic processes there may occur a forced anabolism in the physiologic units of nerve, muscle, and glands, which increases their intrinsic potentials. If the latter

process were demonstrated (the increased capacity to work is a proof) it would show that potentially these currents are the greatest of therapeutic agents. The analgesia at the point of penetration of the current following its application must be owing to depletion of the induced field of the neuromere, thus modifying its molecular spacial equilibrium (§ 150). When blood osmosis replaces the nutritional elements the neuromere regains its equipoise and sequentially its functional activity. The results obtained from applications of these currents throw light upon the relation of the physiologic unit to its induced field. The molecular power of the unit must be supreme within its vibratory space, and the elements of the induced space must have a potential relationship to the potential of the unit, otherwise there is a vibratory block. Moreover, it is conclusive that the induced field contains nutritional elements—potential-carriers of oxygen—in which there is combustion initiated by the current. It is apparent that it is not necessary for a medicinal agent to act chemically on the unit in order to functionally influence it. The presence of the agent within the vibratory space, or the overlapping of the field by the inductive potential of the agent, the initiation of metabolism in the field, or the neutralization of its potentials, will disturb the spacial equilibrium of the unit, and thus interfere with its polarization on which is based its function. The negative potential of the unit must regulate the inter-unit space (induced field), and the elements within the space must have potentials and dimensions bearing an equilibrating relationship to the inductive potential of the unit. These are factors of the equipoise, but which are modifiable by pressure and temperature. It is obvious that a disturbance of

either is a disturbance of the vibratory equilibrium in which there are alternating rest (electric) and polarized (magnetic) conditions, and with varying nutritional and waste modifications.

CHAPTER XXXII

General Application of Electricity

(*Galvanic Current*)

318. Central Galvanization. One pole is placed on the epigastrium and the other is moved successively over the forehead, summit, over the cervical region, along the inner border of the sterno-cleido-mastoid muscle, over the nape of the neck, and along the entire length of the spine. The whole central nervous system—cerebro-spinal and sympathetic systems—is thus brought under the influence of the current. In fact the principal centers lie in the path of the current from the summit to the epigastrium.

Applications traversing the brain should not be continued over one or two minutes, and the length of the seance for central application should be confined to a limit of ten to fifteen minutes. The dosage varies from 2 to 5 milliamperes when traversing the brain; from 20 to 30 when applied to the spine. Shocks should be carefully avoided. No interruptions of the current, by lifting the electrode, should be made, and the effects should be carefully watched and annoyance to the patient avoided by an excess of current. The application to the spine may be labile in character, paying special attention to the celio-spinal center between the first and seventh dorsal vertebræ. The application

influences the pneumogastric and sympathetic, thus affecting the respiratory and circulatory apparatus.

The electrode placed on the epigastrium should be broad, and may be composed of sponge or felt. For the active electrode a small sponge is the better. The positive pole is usually applied to the head, the negative to the abdomen, but in polar differentiation regard must be had to pathologic conditions (§ 305).

Central galvanization is useful in hysteria, chorea and allied affections where there is a hyperirritability and exhaustion of the nervous system. In neuralgia depending on a dyscrasia, in skin diseases of constitutional origin, in chronic diseases of uncertain pathology, in neurasthenia, epilepsy, nervous dyspepsia, hypochondria, and in some forms of insanity, this mode of applying the galvanic current is useful. Modifications of nutrition, both general and local, being important factors in the causality of these diseases, the action of the current in this respect alone is sufficient to justify attention to the mode of treatment. The author found central galvanization useful in allaying persistent vomiting which accompanied a case of clorosis.

Faradic Current

319. General Faradization. Place one pole under the feet, or at the coccyx, whilst the other is applied to various parts of the body-surface. The application may be stable or labile according to the indications of the case. An excellent method is to place one pole in the vagina and to parade the other over the surface. Usually the labile pole is made positive. The strength of the current may be increased as the seance proceeds, the patient thus tolerating a larger dosage.

The various parts of the body are brought directly under electric influence, the application being made to each organ modified in detail as indicated by the character of the specialized structure. Thus the active electrode is passed over the head, neck, spine, and upper extremities, stimulating various groups of muscles of the chest, abdomen, and back, dwelling on the parts sufficiently long to produce distinct reactions.

The following are the principal parts that may be directly influenced by the current:

The Head. The electrode--the operator's hand may be employed—is passed over the forehead for a short period, afterwards it may be placed on the summit, the hair being well moistened. Here the current has to be slight owing to the bony structure and the superficial nerve fibers. The application should last one or two minutes.

Cervical Region. This embraces the cervical spine and the cervical sympathetic and pneumogastric. The electrode should be passed along the anterior border of the sterno-cleido-mastoid and over the celio-spinal center. The current can be of decided intensity and may last from three to five minutes. The important structures in this region make the application a very important factor in general faradization.

Upper Extremities. Here massage of the muscles should be effected by agreeable contractions.

Spine. The sponge should be passed along the entire length with a strong current. The nerve supply of the whole body can be influenced through spinal faradization. The genito-urinary organs, the intercostal muscles and the various viscera have their nerve supply either directly or indirectly from the spinal

cord, and thus reflexly or directly are influenced by the application.

Genitals and Lower Extremities. The electrode may be passed along the surface, contracting the muscles and stimulating the circulation. In applying faradization to sensitive patients it may be necessary not to prolong the seance beyond a few minutes, in which case applications to the spine and neck may be made alone.

The frequency of the seances is an important feature in general faradization. This may be made every day or once or twice a week. In certain cases the tonic effect is produced and sustained by applications every other day. When there are reactive effects the intervals should be prolonged, so as to allow the permanent tonic effects to be developed. The treatment should be persisted in for weeks or months, and the importance of this should be impressed on the patient at the commencement. In the majority of cases general faradization produces a feeling of exhilaration, whilst the tendency to sleep is manifested in others. Pain is often immediately relieved, thus inspiring confidence in the treatment, and, although the relief is sometimes temporary, it often becomes permanent. Weariness and nervousness frequently disappear. Sometimes disagreeable symptoms are immediate results of general faradization, amongst which are coldness of the extremities, perspiration, faintness and dizziness. To overcome these the patient should rest a short time. Generally a feeling of well-being succeeds. The temporary unpleasant results do not contraindicate the current and are entirely consistent with permanent beneficial effects.

Amongst the results of general faradization are:

Restful Sleep. Improvement in sleep sometimes is immediate, decided and permanent.

Equalization of the Circulation. Hysterical and neurasthenic patients often suffer from cold extremities and are benefited by this treatment. Pelvic congestion is often kept up by defective circulation, and here permanent improvement may be predicted

Hyperirritability of the nervous system is a symptom calling for the soothing action of the high tension faradic current. The improvement in the local symptoms reacts on the nervous system, whilst the current in allaying the general hyperirritability influences the local condition. The applications promote a nervous equipoise.

Surgical Operations often remove the primary cause without producing betterment in the general or even local sequential conditions. Here is a field for the employment of electricity, and especially faradization, of which the surgeon does not avail himself.

Amongst the other effects of faradization are regulation of the bowels, increased assimilative power and improved nutrition. The disposition and capacity for work of a physical or mental character are enhanced, and the wear and tear is lessened, as nerve action becomes physiologic.

The idiosyncrasy of the patient, the changing mental condition, and the varying attending symptoms of particular diseases cause the results to lack uniformity. As a rule a person of an actively nervous disposition responds more readily to treatment than the phlegmatic. Differentiation in personal equations demands different treatment-values.

Local Application of Electricity

320. Electricity is applied locally when it is desired to influence a locus morbi which can be brought within the interpolar space. Either current may be used, thus there is localized galvanization, localized faradization and localized franklinization. The head, the cervical region, spine, pelvic cavity or any other part of the body may be the seat of a pathologic change which may be favorably influenced by local electrization.

Local Galvanization

Galvanization of Head. Longitudinal—one pole on forehead and the other on the occiput; *transverse*—from ear to ear, or mastoid to mastoid; or *summit*—one pole on the summit and the other on an indifferent part of the body.

The current should be turned on and off gradually, avoiding shocks, and the seance should be limited to a few minutes. The physiologic action of the current on the brain should be studied (§ 255). The current should be stable in character and the electrodes should be broad. The dosage may be from one to ten milliamperes, the seance lasting from one to ten minutes. In making the application no pain or distress should be caused the patient.

Galvanization of the Cervical Sympathetic. One electrode is placed below the auriculo-maxillary fossa, and the other over the cervical vertebræ, over any part of the spine, over the manubrium sterni, or indifferently. Another method is to place an electrode on each side of the neck, over or below the mastoid processes. The sympathetic will also be reached by placing one elec-

trode on the manubrium sterni, and the other on some part of the spine. The application should last from three to ten minutes, and the current may be from five to sixty milliamperes.

All applications to the cervical sympathetic involve more or less the pneumogastric (§ 260). Galvanization of the sympathetic is indicated by vaso-motor disturbance, where the circulation is actively or passively congested, or where there is local ischæmia or hyperæmia. In diseases of the genito-urinary apparatus or of the digestive organs it is serviceable. It is useful in exophthalmic goitre.

Galvanization of the Spinal Cord. Place one electrode at the occiput and the other at the coccyx or at intermediate points. One may be stabile and the other labile. One electrode may be placed on any part of the spine and the other on the abdomen. The current strength may be from thirty to seventy-five milliamperes.

The above methods will show the principle of procedure. It is evident that any part of the body may be brought under galvanization by placing one electrode in a proximate position to the lesion, and the other indifferently.

321. *Galvanization of Pelvic Organs.* The *indifferent* electrode may be placed on the abdomen or on the back; or a bifurcated conducting cord and double electrode, one part on the abdomen and the other on the back, may be used for the indifferent pole. The dimensions of this electrode should accord with the strength of the current. The material may be sponge, felt, or any other suitable material. Clay is preferable when large amperage is used. The *active* pole should be attached to an electrode composed of such material

and should be of such shape and size as will allow of proper adaptation to the surface acted upon. Thus there are vaginal, intrauterine, rectal and other electrodes specially constructed for the purpose of particular applications (§ 115).

The pelvic organs may be reached by external application. Placing one electrode, usually a large one, on the abdomen, the other may be applied to the perineum, back, or to other parts as the character and location of the lesion indicates.

The dosage varies from a few milliamperes in the case of a sensitive endometrium to 250 milliamperes in the case of fibroid tumors, thus giving full scope to a discriminating judgment on the part of the operator. The active pole may be either positive or negative, the selection being based on the different physical and physiologic actions of the poles. The selection of the poles and the combining of polar action with proper dosage to meet the causal or symptomatic indication will call for a fineness of selective power on the part of the electro-therapeutist only attained by a thorough knowledge of pathology, combined with distinct and fixed ideas of the physical and physiological properties of currents. In this way the operator is enabled to impersonate the current with a fine electric touch, and endow his administrations with a therapeutic discrimination not otherwise attainable.

322. *Effects of Local Galvanization.* The nutrition of the part is improved. This is especially the case when the negative pole is the active one. An atrophied muscle improves in size and strength, and the same can be said of other organs. Hypertrophied tissue is reduced in size until the normal is attained. This apparent paradox will be understood by considering the

pathology. Electricity stimulates nerve and muscle growth because they respond physiologically to its action. A muscular atrophy is therefore corrected. In hypertrophy of the uterus the muscular contraction assists in absorption of pathologic material, and here electrolysis is also a corrective. Furthermore, the physiologic nerve-action and blood-supply is accompanied by normal pressure and temperature and produce normal tissue-growth, and those are brought about by electric stimulation.

Electric Treatment of Strictures

323. The principle of treatment of one stricture pertains to all, with modifications of instrumentation conforming to anatomical differentiations. The galvanic negative is the great liquefying and absorbing pole and is always indicated. In simple stricture of the uterine cervix, rectum, œsophagus, eustachian tube and other canals the current is never contraindicated and often furnishes brilliant results. The dosage varies according to the sensitiveness of the parts and the surface-area of the active pole. Bearing in mind the fundamental principle of polar action, the operator will never fail to make available the electrolytic and cataphoretic action of the galvanic current in these progressively constricting indurations.

Urethral Stricture. The location, size and length of the stricture should be ascertained. This can readily by done by a urethrometer, or by a bougie à boule, or by a sound. A record of the topography should be made for future reference. In selecting an instrument let it be slightly larger than the size of the stricture. Use a straight handle for the pendulous urethra, and a

curved handle for the membranous portion. Attach it to the negative pole always, placing the positive electrode indifferently. Do not use a non-conducting lubricant. Sterilize the sound electrode, and dip it in glycerine. Passing it gently down to the stricture maintain it in position, with slight force. Remember that it is electrolysis and cataphoresis as taking place at the negative pole that does the work, and not physical force. Gradually increase the current from zero up to a point which the patient feels as a sensation of warmth or tingling at the active electrode. From three to eight milliamperes, according to the size of the electrode, will be borne, and is of sufficient intensity. If the cause of the stricture is a deposit of inflammatory plastic material the electrode will glide through the constricted portion with astonishing ease, in which case it can be drawn backwards, gently as before, through the stricture without reduction of current. Pain should never accompany electrolytic treatment.

If the stricture is made of dense cicatricial tissue, the result of using caustics or of previous cutting, it will offer more resistance. However, the electrode may be maintained against the constriction for twenty to thirty minutes without any disadvantage. The current should be carefully reduced to zero before withdrawing, thus avoiding shock. What is required is the softening and absorbing action of the pole, and not the effect of cauterization, nor the active pressure by the operator.

From five to ten treatments should show improvement if the case is amenable to electrolysis. The treatment, however, may be further tried without affecting the consideration of other and different methods of treatment. The seances can be repeated once a week on an average. When there is hemorrhage produced

by the introduction of the sound, the operation had better be postponed. Dense fibrous bands do not yield readily to electrolytic action, but there is no objection, with the consent of the patient, to prolong the treatment and attempt to soften and absorb them.

Around the membranous portion of the urethra is a collection of muscular fibers—cut off muscle. These contract readily on reflex action from the urethral mucous membrane. It is in this portion where many failures of electrolytic treatment have been recorded. It is suspected that important factors in the cause of failure of the treatment of these cases are the want of patience, and the lack of anatomical knowledge, on the part of the operator.

Electrolysis of urethral stricture is entirely without danger, the negative polarity of the sound facilitates its passage, a fact which has been demonstrated in cases where surgeons have failed to effect a passage. It relieves at once and is applicable to all strictures, and can be performed while the patient is attending to his daily business. The most important consideration is that electrolysis actually removes the pathologic condition, which cannot be said of a cutting operation, therefore no relapses occur after the electrolytic method.

Local Faradization

324. Faradization of the head, neck, spine, and other portions of the body is accomplished by the same methods as are used in local galvanization, and the same variation in dosage is indicated to accord with the sensitiveness of specialized tissues.

The electrodes used are of different material, size and shape so as to be capable of adjustment to the con-

formation of parts, and aid in accomplishing the purpose of the application. Thus sometimes the operator's hand is used as an electrode, sometimes the bare metal—metallic brush or solid metal—or metal covered with sponge, absorbent cotton, felt, flannel, linen, etc., these latter being thoroughly moistened with a saline solution.

Dry Faradization. The hand, a solid metallic electrode, or the metallic brush may be used. The hand is preferable with delicate or timid patients. Applications by the metallic brush may give considerable pain; they are, however, useful in cutaneous anesthesia and neuralgia. In dry faradization the skin should be wiped dry, and absorbent powder may be dusted over it previous to applying the current.

Moistened Electrodes. A large, well moistened electrode may be used for the indifferent pole, whilst the active pole may be attached to a smaller one. It must be kept in mind that the current diffuses in the tissues so as to meet with as little resistance as possible. The size of electrodes varies according to the purpose of the application. In stimulating the motor point of a nerve small electrodes are useful; on the other hand, applying the current directly to a muscle a larger electrode is preferable.

Faradization of the pelvic organs is accomplished by the same methods as are used for galvanization, only in faradization the bipolar electrode has been found an effective and convenient instrument for its application.

325. *Bipolar Faradization.* This simply means the application of the faradic current by an electrode in which the two poles terminate. The galvanic current is not applied by this method owing to practical difficulties. The method therefore is exclusively used in faradiza-

tion, and is practically confined to the treatment of the vagina, uterus, rectum, and the bladder.

When the current passes through soft tissues which electrically connect the two poles of a bipolar electrode it spreads out according to its intensity, thus meeting with less resistance as the cross-sectional area is increased (§ 17). This is an important consideration in using this method.

Fig. 130. Vaginal Bipolar Electrode.

Bipolar electrodes have the advantage of being more easily applied, the patient's clothing not being disturbed and no moisture being needed for the electrode. A larger current is tolerated owing to the mucous membranes not being so sensitive as the skin. A practical demonstration of this is made when the electrode accidentally passes from the vagina and one of the poles touches the labial surface. To prevent this the electrode should be firmly fastened by pinning the clothing over it. Owing to the insensitiveness of the mucous membrane a much larger current can be applied than by having one pole on the cutaneous surface.

Owing to mucous surfaces offering less resistance to the current than cutaneous surfaces a quantitative current, which has little power in overcoming resistances, exercises an immense contracting force over the unstriped muscular fibers of the uterus, vagina, rectum, and bladder. This differential contracting power is particularly manifested when bipolar electrodes are used. On the other hand the bipolar

electrode with a high tension current of great frequency is of great service where there is pelvic tenderness or pain. In muscular relaxation, prolapsus, and in displacements without acute inflammatory action, the bipolar method of application with coarse currents, are curative, if the case is not of too long standing.

CHAPTER XXXIII

Dosage of Electricity, Duration of Application, and Frequency of Seance.

326. *Galvanic Current.* The introduction of the milliamperemeter has rendered possible a scientific exactness in the administration of the galvanic current otherwise impossible of attainment. The dosage varies with the object of the application. If it is desired to produce electrolysis, as in the case of a fibroid tumor, the dosage may range from 50 to 250 milliamperes, if no accompanying conditions contraindicate. Electrolysis, however, takes place with small amperage and is directly proportional to the energy of the current. In hypertrophies and in inflammatory exudations of long standing large dosage can be used—fifty or seventy-five milliamperes. The cataphoretic action of the current is obtained with small amperage—from two to thirty milliamperes—the sensitiveness of the parts, their liquid or solid conditions deciding the particular dosage.

To obtain electrotonic results, only small currents are needed, the pathologic condition and the anatomic relationship of the nerve determining the exact dosage. In facial and other superficial neuralgias a current of one to ten milliamperes is sufficient, whilst in sciatica thirty to forty milliamperes are well borne and are beneficial.

Acute inflammatory action or a sensitive condition of the parts demand small currents. On the other hand, chronic cases with slight sensitiveness will improve under large dosage.

In paralysis currents of ten to fifteen milliamperes are usually sufficient. The nutrition of the part or of the general system should be improved, and it is not always necessary that muscular contraction be effected.

The *duration* of the seance may vary from three to fifteen minutes. Sometimes, when the object is to produce cataphoresis or electrolysis, a small dosage prolonged is preferable to a large current applied for a few minutes; on the other hand, a muscle contracted for three minutes has its nutrition stimulated, while a fifteen minutes' seance may exhaust it.

As a rule repetition of the seance may take place every second day, but when employing very large currents once a week is sufficient, it being kept in view that the effects produced by currents continue for some time after the application.

In using large currents it is often of advantage to employ the faradic alternately with the galvanic. On applying large amperage it is best to increase from zero gradually. When a slight pain is felt stop increasing or even reduce the current-strength slightly. When the patient is comfortable re-commence increasing until the point of tolerance is again reached. By this method very large currents will be tolerated. When the desired amperage cannot be reached without pain investigate the condition of the electrode as to moisture, contact-area, and adaptability to the surface; also see that the skin has no eruptions. The skin may be improved as a conductor by shampooing with hot water

and soap or ammonia, and tissue paper may be applied to abrasions.

Tolerance of the current may be increased after a few seances properly conducted. If, however, the case should prove refractory, no effort should be made to go beyond the tolerant point and thus cause pain and dis-

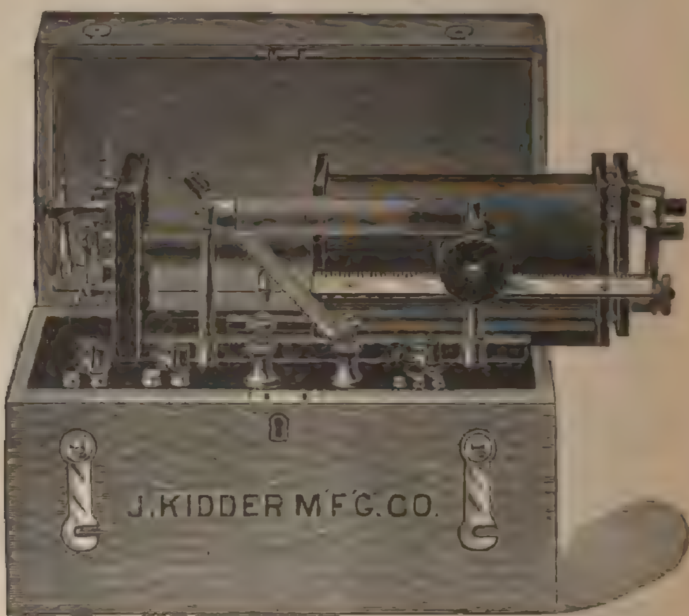


Fig. 131.
High Tension Faradic Apparatus, Continuous Coil.
(*Jerome Kidder Manufacturing Co.*)

tress. If tolerance decreases as the treatment p gresses it is a signal for caution, and if pain is a re of treatment it is a positive warning that some ch in the kind of current, dosage, length of seanc mode of application must be made; or that el treatment is contraindicated.

327. *The Faradic Current.* The faradic current cannot be measured by the galvanometer, owing to the mechanical impossibility of the needle following its vibrations. However, the sensations of the patient furnish a measurement which is generally a sufficient guidance to correct dosage. The rule that pain should not be caused the patient is absolute. For the relief of pain a small current of high tension and rapid vibration is usually indicated. Where the nerve is deeply situated larger force will be borne, while superficial nerve trunks, especially if passing over bony prominences, will tolerate only small currents. It is better to err on the side of small than that of large currents; and until the idiosyncrasy of the patient and the tolerance of the tissues are ascertained small currents should be employed. The immediate and remote effects of the applications should be studied in order to direct the operator in future seances. It must not be forgotten, however, that immediate results may cause annoyance and remote effects be entirely beneficial.

The *duration* of the faradic application may be from three minutes to half an hour. A relaxed muscle, stimulated by a coarse, slowly interrupted current, is strengthened by a three-minute application; on the other hand general faradization may be extended to half an hour.

Faradization may be applied several times a day, as in the treatment of sciatica or other neuralgias, or two or three times a week, as in general faradization.

328. *Franklinic Currents or Static Electrification.* The nature of the pathologic condition which it is desired to remove, the tolerance of the tissues and the idiosyncrasy of the patient must direct these applications as in the galvanic and faradic currents. From

simple electrification to strong sparks there is a range of dosage which will allow the judgment and fineness of the electric touch of the operator ample room for display, and which will meet the indications of a large variety of conditions.

The *duration* of the application and the *frequency* of the seances are subject to the same general principles laid down for galvanization and faradization. The dosage of franklinic currents is regulated by the revolution of the plates from slow to fast; by diverting the electrification away from the patient; by re-enforcement of the electrification by Leyden jar condensers; and by the skill of the operator in handling the apparatus.

CHAPTER XXXIV

Electro-Diagnosis

328. As all parts of the body are in some way responsive to electric applications, varying in accordance with their physical and functional characters, and as the response is modified by disease, it is clear that there is a basis on which electro-diagnosis may be established.

The modification of the normal electric response, or of the normal electro-sensibility of an organ, may be either an increase or a decrease. The great practical difficulty is in establishing a standard of physiologic electro-sensibility, as organs vary largely in functional response to the current, and are still within physiologic limits. We can only compare, when practicable, the electro-sensibility of the suspected organ or part, with the sensitiveness of the corresponding organ or part of the opposite side, being careful to have the same relative placement of the poles, the same sized electrodes, with the same degree of moisture, and under the same conditions generally.

A standardized faradic apparatus has been proposed, in using which physicians could compare results, but so far this is outside the sphere of practical electro-therapeutics.

As a whole, electro-diagnosis has not arrived at that point of scientific exactness which would recommend

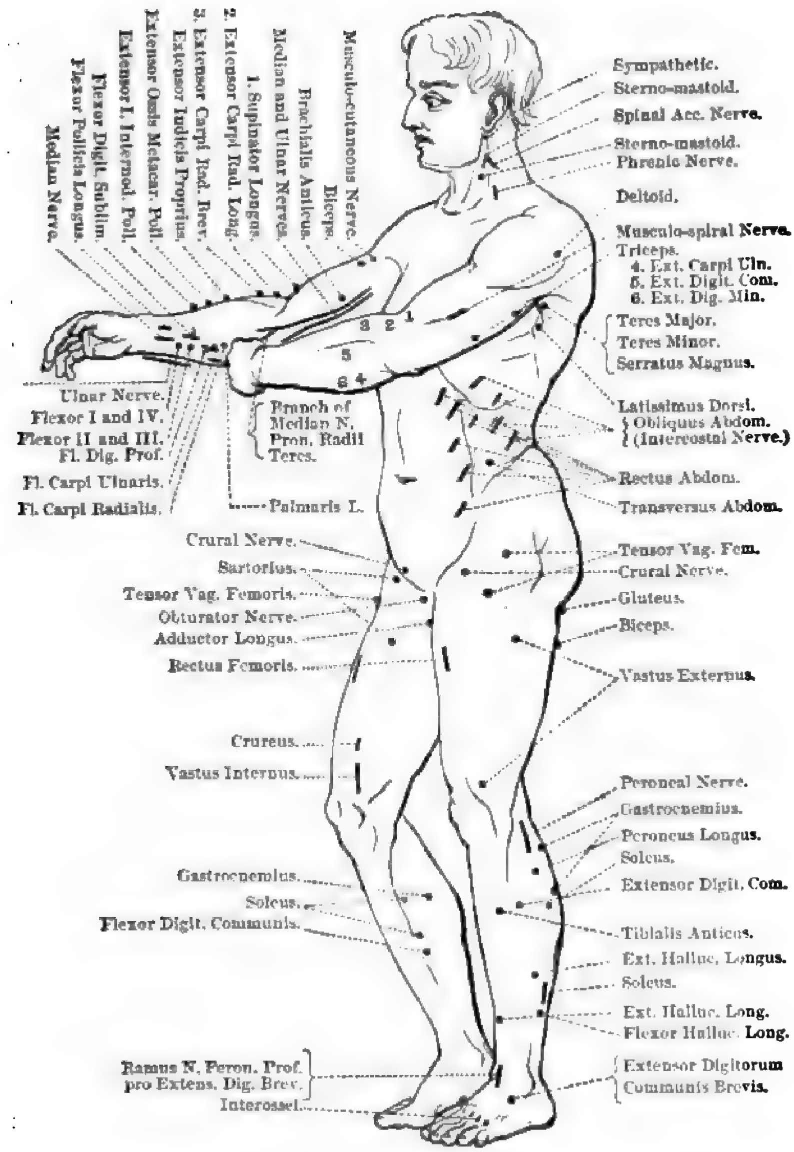
it to the practical and busy electro-therapeutist, and yet, in clearing up undetermined but suspected conditions, and enabling us to arrive at a proper diagnosis of cause, as well as at an early prognosis, electricity has furnished brilliant instances, and electro-diagnosis will be ever an attractive subject.

329. *Motor points* are locations on the body-surface at which galvanic stimulation of a muscle is most easily effected. They usually correspond to points where motor nerves enter muscles. A general knowledge of anatomy is all that is necessary to enable a practitioner to find any motor point desirable. An excellent method is as follows: Employ an induced current of high tension, and place one electrode, comparatively large, on the opposite side of the part to be examined, such as on the back of the forearm, if the flexors of the hand are to be examined, or over the spine if the abdominal muscles are to be tested. Then, with a smaller electrode, well moistened in a saline solution, parade the surface of the muscles, and when the motor points are reached, contraction will ensue. Fig. 132 indicates the motor points.

Before making comparisons, the minimum amount of current necessary to produce contractions should be ascertained, and it is better to use the negative as the active pole in comparing the irritability of corresponding muscles (§ 197).

330. When a normal muscle is excited by electric applications its response is immediate, quick, lightning-like. In disease this may be modified, and the muscle may become lazy, drawing itself up slowly. This is called sluggish contraction.

Again, the normal formula of electric sensibility may be changed. The relative order in which con-



Motor points of trunk and limbs.

Fig. 132.

Motor Points. (*Lippincott's Medical Dictionary.*)

traction takes place is as follows: (1) K Cl C; (2) An Cl C; (3) An O C; (4) K O C (§196–199). When the normal formula of electric reactions is changed it is said to be a *qualitative*, and when the sensibility is merely increased or diminished it is said to be a *quantitative* change.

The change that takes place in the normal formula is remarkable. The anodal closing contraction responds gradually to weaker currents, until it is excited by an amount of current equal to that of the cathode closing contraction. The anodal opening contraction and the cathodal opening contraction also approach in degree of excitability the cathodal closing contraction. The change taking place in the normal formula of electro-contractility, and which is also associated with quantitative changes, has been termed the *reaction of degeneration*—R. D.

Although increased or diminished irritability is generally the same for both galvanic and faradic currents, occasionally it is found that one is increased and the other diminished.

Individual phenomena, associated with degenerative changes, are best studied from a typical case, as in Bell's paralysis. The electric reactions appear about as follows:

Nerve. After a slight increase of irritability, there is a gradual decrease until the end of the second week, when both galvanic and faradic irritability disappear; voluntary movements then become impossible.

Muscles. Gradual decrease of faradic irritability and increase of galvanic irritability are the first manifestations. Sometimes galvanization of the well side will produce contraction of the paralyzed side. Mechanical

irritability is also increased. Galvanic hyperirritability usually lasts several weeks, and then subsides.

The most characteristic sign of the reaction of degeneration is the sluggish contraction, which is coincident in appearance with the galvanic hyperirritability. The change of formula also occurs early in the process of degeneration. After four to six weeks irritability is lost, the An Cl C being the last to disappear; or a slight response to voltaic alternation may be the last to manifest itself.

Regeneration of the nerve is announced by trophic activity, then comes voluntary power, which is followed by electric irritability. The muscular irritability is re-established in the reverse order of its disappearance as noted in the change of formula. Regeneration of the nerve takes place from the periphery.

The degenerative changes in the muscle, when not arrested, end in its assuming the appearance of a thin cord-like band of fibrous tissue with traces of muscular nuclei. The motor end plates are the last to yield, and the first to be restored.

331. The fact of the muscle responding to galvanic stimulation and not to faradic has been explained, on the ground that sluggish contraction, caused by degenerative changes, prevents the reaction taking place before the succeeding faradic interruption.

The modification in the normal formula may be explained by the degenerative changes being accompanied by a reduced potential of the muscular molecule, whereby it becomes more affected by positive electricity, and the histological elements of the muscle become more completely polarized when under positive polar influence (§ 199, § 200). If the metabolism of muscle and nerve consists of the taking on and giving

off of carbon, hydrogen, and oxygen (§ 160, § 162), an exhaustive or degenerative cell or cell-molecule must lose in its relative negativity, as the ionized oxygen has a more negative potential than ionized carbon and hydrogen have positive potential (§ 27, § 28). The molecule of a degenerated cell therefore consists of the stable base (§ 161) of about equal positivity and negativity, and the negative potential of a normal cell-molecule resides in the resultant negativity of the ions, carbon, hydrogen and oxygen, when associated as hydrogen carbonate. Hence it is the negativity of the nutrient molecule, H_2CO_3, which gives character to electric muscular response as expressed by the normal formula, and the negativity is lessened by the nutrition being shut off (§ 162). Under these conditions the physiologic unit becomes neutral or even electro-positive. It would be interesting to know what changes take place in the extra polar after-currents of a section of degenerated nerve. It is probable that the difference in the direction of anodal after-current would disappear (§ 201, § 202); and that the quality and position of the leading off point might be modified.

332. The reaction of degeneration is of diagnostic and prognostic value. It is not present in lesions confined to the upper segment of the motor tract—the cortex, descending motor pathways, the internal capsule, the crura, the pyramids or the lateral columns of the cord.

In lesions of the lower segment of the motor tract—the anterior cornua of the gray matter of the spinal cord, the cerebro-spinal nerves or their ultimate terminal distributions—it is generally present. In myopathies irritability is merely decreased.

The electro-contractility of a muscle may be (1) normal; (2) quantitatively changed; or (3) qualitatively changed.

1. The reactions are normal when there is no interference with the nutrition of the neurone and muscle. Hence they are normal in all cerebral diseases whether organic or functional—hemiplegia; hysteria, epilepsy, etc.

Diseases or secondary affections of the white columns of the cord such as locomotor ataxia, lateral sclerosis and spinal sclerosis may show slight quantitative changes, but only in the later stages.

Transverse myelitis, compression or injury of the cord, will only show degenerative reactions in the nerves and muscles innervated by the diseased portion. Slight palsies from cold or pressure may not show degenerative changes.

2. Increased faradic irritability of nerve or muscle is found in tetanus; and may be found in hemiplegia, with irritable reflex centers and contractured muscles.

Increased galvano-muscular irritability is present in the early stages of degeneration.

Decreased or abolished irritability of the nerve to both currents accompanies degeneration. In long standing cases of lateral and posterior sclerosis or cerebral palsies there may be a diminished excitability.

3. The reaction of degeneration is present in the following diseases: Diseases affecting the anterior cornua, thus implicating the nutrition of the motor neurone, as myelitis caused by pressure, injuries, toxic agents, syphilitic deposits, etc.; poliomyelitis; bulbar paralysis; lead paralysis; atrophic lateral

sclerosis (early stages); cases of diphtheritic paralysis; inflammation of motor neurones, traumatic or idiopathic; multiple neuritis; peripheral palsies, from whatever cause, in which the integrity of the neurone has been seriously attacked.

When the question lies between a cerebral or peripheral origin of facial paralysis or paralysis of a limb the presence or absence of R. D. or normal farado-muscular response is conclusive. The character of electro-muscular reactions will differentiate also between cerebral, peripheral and lead palsy. Normal reactions are of positive value in a number of cases; whilst in others the R. D. with the aid of other testimony often decides the diagnosis.

333. For convenience paralyses may be classified as follows:

1. CENTRAL PARALYSIS. BRAIN. *Causes.* Apoplexy, thrombosis or embolism, tumors, resulting in hemiplegia, diplegia, etc.; softening, as in bulbar paralysis.

SPINAL CORD. *Causes.* Myelitis, meningitis, softening, sclerosis, compression from hemorrhage, tumors, or abscess; resulting in paraplegia. Injury or compression of one side may cause spinal hemiplegia.

2. PERIPHERAL PARALYSIS. *Causes.* Neuritis, injury, exposure, pressure from growths, etc., destruction of nerve tissue by suppuration, etc.

3. CONSTITUTIONAL PARALYSIS. *Causes.* Gout, rheumatism, syphilis, scarlet fever, diphtheria, typhoid fever, small-pox; poisons, such as lead, mercury, opium, arsenic, phosphorus; hysteria.

4. REFLEX PARALYSIS. Due to the motor pathway being in possession of extraneous impulses initiated in a distant organ.

The motor pathway lies between the cerebral cortex and the muscles. It is divided into two segments or systems, the upper and lower.

The *upper motor path or segment* consists of a strand of fibers known as the pyramidal tract. It commences with the axis cylinder processes of large pyramidal cells in the cerebral cortex. The collective fibers constitute part of the corona radiata, which gathers itself into the internal capsule. It passes from the capsule into the crus cerebri, hence to the pons, and through the bulb to the spinal cord, where it forms the anterior columns. As it descends through the cord it becomes more attenuated and finally terminates in the lumbar enlargement. The greater part of the fibers of the tract decussate as they pass through the medulla, the others pass directly into the cord.

The mode of termination of the pyramidal fibers in the cord is by forming arborizations about the root-cells of the anterior horn. No anatomical connection has been traced between the root-cells and the arborizations. These arborizations are the lower terminals of the upper segment. The lower segment of the motor pathway begins with the multipolar ganglion-cells of the anterior horns of the cord and the corresponding root-cells of the cranial nerves. The axis cylinders of these cells are continuous with the axis cylinders of the motor nerve fibers which ultimately end in the motor plates of the muscles.

Paralysis having its origin in the upper segment of the motor pathway, that is between the cortex and the multipolar ganglion-cells of the anterior horn, exclusive of the latter, will exhibit the following characteristics:

The muscles are in condition of spasticity, never flaccid. They resist passive movements, and contrac-

DIFFERENTIAL DEGENERATIVE CHANGES AS SHOWN BY ELECTRO-NEURO-MUSCULAR REACTIONS

	Nerve		Muscle		Character of Contraction	Formula	Atrophy	R. D.
	Galv. irrit.	Farad. irrit.	Galv. irrit.	Farad. irrit.				
1. Paralysis...................	normal	normal	normal	normal	normal	normal	none	none
2. Paralysis...................	decreased	decreased	increased	decreased	slow	changed	slight	partial
3. Paralysis...................	abolished	abolished	increased	abolished	sluggish	changed	moderate	complete
4. Paralysis...................	abolished	abolished	weak, only by strong currents or V. A.	absent	weak and slow	changed	extreme, cord-like	complete, if any response

Prognosis. The prognostic value of the reactions as shown in the tabulation depends on the seat and character of the primary lesion. Two weeks should be allowed to pass before making tests. Generally, the more pronounced the reaction of degeneration the graver the prognosis. A peripheral paralysis from pressure without external wound, exhibiting slight or no electric changes, probably will be of two or four weeks' duration, whilst peripheral paralysis from the same cause exhibiting the reactions of the second class, may last from two to five months. The intensity of manifestation of the phenomena of R. D. of the third class denotes serious involvement of structures, and a protracted course. At best this form will last from six to nine months. In extreme degeneration of the fourth class, from peripheral nerve lesions, recovery will take place probably in one year. In anterior poliomyelitis a muscle responding, however slightly, to the faradic current, insures a favorable prognosis.

tures take place. They become atrophied from inaction, but there are no degenerative processes, and no electric reaction of degeneration. The paralysis is on the opposite side of the body if the lesion is above the decussation, although slight paresis may exist on the same side.

Paralysis having its origin in the lower segment of the motor path, shows muscular flaccidity, and there is a lessening of tone. There is no resistance to passive movements and no contractures. The neurone body being shut off there is absolutely no reflex action, and the complete disuse ends in atrophy and degeneration.

The electric reactions are changed from the normal, both in the nerve and muscle. The farado-muscular contractility is diminished or abolished; galvano-muscular contractility is increased, normal or diminished. The contractions become sluggish, the formula is changed, and the reactions of degeneration more or less pronounced.

334. Common Sensation. The two variations from the normal are hyperesthesia and anesthesia. In testing the condition of the sensory nerves the active electrode is constructed so as to present to the surface examined as many points as possible. Erb devised an instrument of this kind consisting of 400 fine insulated wires, ground off so as to present a smooth surface allowing even contact with the skin. This forms the active electrode, the other being placed indifferently. The secondary coil of a faradic apparatus is used.

Beginning at zero the current is increased until the sensation of the force is felt, which is noted. Then the current is increased until pain is felt, which is also noted. The corresponding reaction of the opposite side

of the body is then ascertained and comparisons drawn.

Examination of common sensation is important in locomotor ataxia where the sensibility of the whole body-surface is decreased. The sensibility to pain is generally decreased in proportion to the decrease of general sensibility, but in some cases there is complete analgesia.

In diseases unilateral in character the farado-cutaneous sensibility will show a distinct difference in the sensibility of the two sides. It must be remembered that cutaneous sensibility varies in different areas of the body-surface. In general, organs which are hypersensitive through disease are more sensitive to the current than when in health; on the other hand, when there is a loss of sensation from disease there is a corresponding loss of appreciation of electric applications. Accordingly where there is acute inflammatory action there is intolerance of electricity, and when there is induration or atrophy there is great tolerance. The different sensitiveness of parts in health should be noted. Electro-sensibility is particularly marked over prominent nerve-tracts, and in regions having great tactile sensibility. In certain diseases particular regions are oversensitive to the current. Thus the epigastric region is abnormally electro-sensitive in dyspepsia. Electro-sensibility may be normal when there is a diminished common sensation. In posterior spinal sclerosis a moderate electric current may be perceived when almost complete analgesia exists.

The faradic current, owing to its greater mechanical power, is the better for diagnostic purposes. The galvanic supplements the faradic current, being useful when faradic irritability is absent. The weakest current to produce a reaction is preferably used. The

difference in the poles of the faradic current is only relative, the reactions, however, are greater at the "break" than at the "make" (§ 84) and the current produces more pronounced results at the faradic cathode (§ 88, § 86).

335. PELVIC DISEASES. The suspected existence of cystic or cancerous degeneration will be confirmed by the absence of responsive symptomatic improvement when current applications are made, but in these conditions no post operatory disturbance will ensue. A pelvic pus collection contraindicates the use of electricity, and will be announced by post operatory symptomatic exacerbations. Acute inflammatory action taking place in any part of the pelvic cavity will announce itself when large amperage is employed, and more especially by the intrauterine method.

It must be noted, however, in this connection, that intensification of the existing symptoms, or even the creation of new ones, may immediately follow electrical seances at the commencement of treatment, when the ultimate reactions are entirely beneficial, and when no contraindication exists. An electro-therapeutist should not be discouraged in any case by the want of success on making one or a few applications, as the fault may rest with the dosage, length of seance, mode of application or kind of current.

336. FEIGNED DISEASES. Here the application of the electric currents are of use. A person feigning paralysis of motion or sensation cannot resist contraction of the muscles, nor the pain produced by strong faradization; on the other hand, the question in favor of disease may be settled by such application.

APPARENT DEATH. Electric contractility usually disappears within three hours, thus it will be seen that

the current is an important method of distinguishing death from apparent death.

EXAMINATION OF THE EYE. A distinct sensation of light and perception of color takes place with a current of one milliampere applied to the healthy eye. The eye should be able to discern between the positive and negative as the active pole. The absence of perception of color or of light itself, and the inability to distinguish the poles, point to inflammation or atrophy of the optic nerve.

The method of procedure in making examination of the eye is as follows: Place a flat sponge electrode on the back of the neck, on the side of the eye to be examined, so that the diffusion of the current does not affect the other eye; place the active electrode over the closed lid. Both eyes should be closed during and for a few minutes before the examination, or the examination may take place in a dark room. The meter used should be capable of measuring a fraction of a milliampere.

CHAPTER XXXV

GYNECOLOGICAL ELECTRO-THERAPY

General Considerations

337. No work on diseases of women should be written without paying tribute to the genius of Apostoli, to whose persistent efforts electric currents, as applied to pelvic diseases, have been put on a scientific basis. Apostoli's successful treatment of fibroid tumors by scientifically-applied currents did more to attract the attention of the specialist in gynecology than any other event in the history of electro-therapeutics. His success, and his steadfast advocacy of his discovery, attracted the attention of the most eminent surgeons, notably Dr. Thomas Keith, of London, who was the first to remove large numbers of fibroid tumors with the knife, and who afterwards announced in his work that he had given up all other treatment and adopted that of Apostoli.

Apostoli was the first to demonstrate that powerful currents could be introduced into the body painlessly and effectually by diffusion on its surface, although the idea had been previously conceived by Erb. There are two essential requisites for the successful application of electricity to diseases peculiar to women: (1) A special knowledge of pelvic pathology; (2) a special knowledge of the principles of electricity as a therapeutic agent.

It is because of a deficiency of knowledge on the part of operators, in one or both of the directions indicated, that electricity has failed to become popular amongst physicians as an agent in the pelvic diseases of women. There is no branch of medicine or surgery where the result of treatments emphasizes the necessity of a correct diagnosis and a rational adjustment of the agency to the pathological condition, as in electro-gynecology. Hence there are failures, hence also there are brilliant successes.

The claims of electricity to a place in gynecological therapeutics are as follows: It regulates the circulation of the whole pelvic cavity, corrects nutritional faults, stimulates functional activity, stops hemorrhage, relieves pain, destroys microbes, causes retrogression of benign tumors, and in its action always tends towards the normal, thus restoring general and local health. Electricity when scientifically applied is absolutely without danger or risk of either mutilation or more unfortunate results. In addition its general sedative action in allaying the accompanying nervous hyperirritability and promoting sleep and comfort deserves consideration. The galvanic, faradic, and static forms of electricity are used and each have special advantages in meeting indications for electrical treatment in gynecological practice.

338. *Central Galvanization* is a powerful stimulus to the organs and functions generally, and is of special advantage in all cases where the rest cure is indicated, reacting locally on pelvic pathological conditions. This and other methods of application may be followed by some depression or dizziness which lasts a short time, when a comfortable warm reaction ensues.

General Faradization. The current of high tension for its general tonic effect, and a coarser current of quantity for its mechanical influence, are used in this manner. One electrode may be placed under the feet, in the vagina, or indifferently, and the other applied to different points of the body—to the breasts, spinal or abdominal centers.

Abdomino-Dorsal Applications. These are applicable when there is an accompanying disturbance of organs such as the liver, bowels, stomach, etc., and of the abdominal sympathetic centers. They may be substituted for vaginal applications when introduction of an electrode into the vagina is inadvisable.

Spinal Applications. These are valuable in amenorrhea of nervous origin where direct applications are objectionable.

Vaginal Applications. Galvanic. One electrode—the active—is placed within the vagina and the other indifferently on the abdomen or back. When the active pole is negative the electrode may be of any material; it being positive necessitates a non-oxidizable substance such as carbon, clay, etc.

The electrode should always be covered by some material such as cotton, which should be well moistened with warm water, and soaped. The selection of the active pole is important, depending on the pathological condition to be corrected.

Vaginal applications are useful not only for diseases of the vagina, but sometimes as the best available method of concentrating the current on the uterus and adjoining structures. It is often necessary to use large currents—100 or 150 milliamperes—and the vaginal mucous membrane should be carefully pro-

tected from cauterization by an efficient electrode covering.

Faradic Vaginal applications may be either *monopolar* or *bipolar*. That is, one pole may be placed within the vagina and the other in an indifferent position; or the bipolar electrode—both poles on one instrument—may be introduced (Fig. 130). The current from the bipolar electrode fills the whole pelvic cavity, affecting the nerves distributed to the lower extremities, and is a most effective means of applying the interrupted current to the pelvic organs. This method is confined to faradization and not available with the galvanic current. The bipolar method has the advantage of having the electrode only in contact with the mucous membrane, which is not so sensitive to the current as the skin, therefore a larger current is tolerated. Care should be taken that the electrode is kept in position in the vagina, as it is apt to slip backward, when the hinder pole will come in contact with the skin, thus causing pain. Very large currents can be applied in this way, and applications can be made daily with advantage. Vaginal faradization is an excellent method of influencing the sympathetic system when there is a general nervous disturbance, associated with pelvic ailment.

Intrauterine applications. Galvanic. These are always monopolar, the active pole being within the uterine cavity and the indifferent on the abdomen or back. The electrodes are sound shaped and insulated to within two and a half inches or less of the point, thus protecting the vagina. Insulation may be effected by heating the sound in the flame of an alcohol lamp and covering it with gum shellac; or by enveloping part of a common uterine sound in soft rubber tubing.

Too great care cannot be taken against sepsis, and exposing the electrode to the flame of an alcohol lamp, or placing it in boiling water, is a good method of securing asepsis. The intrauterine portion of the sound may be bare or covered with cotton, the covering tending to prevent cauterization.

For the negative pole any available conducting material can be used; the material of the positive, when only the action of the current is required, should be platinum, carbon, or gold.

Metallic cataphoresis or amalgam cataphoresis is very useful in certain cases of endometritis, and has been recommended by Massey for incipient cancer. The amalgam electrode has the advantage of not adhering to the tissues.

As a rule no speculum is necessary, and the dorsal position is the one most available. The indifferent electrode is made of clay or other material, and is large or small according to the amount of current and sensitiveness of the skin. Every thing connected with the battery should be examined before turning on the current, as an accidental break in the current will cause a severe shock to the patient. The duration of the seance may be from five to twenty minutes, and the strength of the current from 3 milliamperes to 250.

The patient having assumed the obstetrical position, the muscles relaxed, and the skin examined for lesions, which if existing should be covered with paper or collodion, the electrode should be well adjusted, but should not touch the pubes, and the clothing should be protected from wet by a towel. The intrauterine electrode then should be examined and gently introduced. The current should be turned on gradually, the operator keeping his eyes alternately on the patient's face and the milliamperemeter. On the first sign of an ex-

pression of uneasiness on the part of the patient the controller should be stopped. A slight backward movement will relieve pain. When the pain subsides an advance may be made until the highest tolerance is reached, or the desired amount of current obtained.

Consciousness of the current at the internal electrode shows the approaching limit of tolerance; and internal pain is a signal for caution, or that the limit has been reached. On the other hand, pain at the indifferent pole is a notice that the conducting surface is at fault, or that the electrode should be enlarged in area. When the milliamperemeter has marked its highest it should be kept there steadily for the required time, and then the current gradually lessened; remembering always that if too rapidly withdrawn the reverse or polarized current, causing first of all depolarization, and then polarization in the opposite direction of the molecules of the tissues, will produce a shock to the patient. The patient should rest for some hours after treatment, and should be warned that there may be some reaction, that she may have abdominal pains followed by soreness, and that there may be a temporary leucorrhea.

Contraindications. Pregnancy, acute inflammations of the uterus, or adnexa, or pelvic pus collections, contraindicate the intrauterine method of applying currents. After the pus cavity is evacuated, or the acute inflammatory symptoms subside, intrauterine applications may be employed.

339. *Faradic Intrauterine Applications.* These may be monopolar or bipolar, and may be either high or low in tension, with rapid or slow interruptions. The sinusoidal current may be used. Faradic applications are useful in finishing a galvanic seance where disturbance

is anticipated from large dosage. For the same purpose faradic seances may alternate with galvanic. In the latter case vaginal faradization is preferable to intrauterine.

In general, when intrauterine applications are indicated the treatment should be initiated by vaginal applications of either the galvanic or faradic current, thus gaining the confidence of the patient, estimating her idiosyncratic tendencies, and manifesting contra-indications to the more disturbing intrauterine method, or to pelvic electric applications.

Static or Franklinic Applications. Whenever there is constitutional involvement associated with pelvic disease, whether the general condition stands in the relation of cause or effect to the local trouble, static electricity is indicated. The improvement in the general health will be associated with a corresponding local reaction, whether the impairment is manifested as neuralgia, anemia, neurasthenia, dyspepsia, or the various menstrual derangements such as amenorrhea, menorrhagia or dysmenorrhea. Static electricity will aid local treatment in cases of fibroids, endometritis, metritis, displacements, oophoritis, and more especially in functional disorders attending the menstrual period. In cases of long standing static electricity is beneficial, generally in a degree beyond that attained by any other remedy.

340. Inflammation of the Cervix

(*Chronic Endocervicitis; Chronic Cervicitis*)

Causes.—Catarrhal inflammation of adjoining structures, gonorrhea, sepsis, laceration, and displacement of uterus are causes. Imperfect involution after labor or

miscarriage, and scrofulous or tuberculous diathesis predispose.

SYMPTOMS. — Leucorrhea, thick, tenacious and opaque, often profuse, rarely purulent or bloody, is usually present. Backache and discomfort around pelvis are often present; and there may be considerable local tenderness. The cervix is frequently swollen and eroded, the squamous epithelium exfoliating around the os, due to the extension of the inflammatory process. The racemose glands become obstructed and cysts form—cystic degeneration. There may be prolapse of the endometrium and later sclerosis.

TREATMENT.—To relieve the tenderness is the first indication, and this may be done by sedative faradization, monopolar or bipolar. If the secretion is thick and tenacious use negative galvanization, or negative cataphoresis of iodine. A dosage of about fifteen milliamperes for five to ten minutes is sufficient. After the membranes are cleansed and secretion thinned by negative galvanization, use zinc, copper or mercurial cataphoresis, or in light cases merely positive galvanization. Sedative faradization can follow the galvanic seance or the induced current can be used exclusively at a sitting so as to meet the symptoms, general or local. Tampons, hot douches and other treatment can be kept up.

When sclerosis has taken place the negative current is indicated. Scars can be softened by the negative electrolysis, and erosions and even ulceration benefited by negative stimulation, through the improvement of the local nutrition.

When the tissues are soft and œdematous the positive pole is the better, using the platinum electrode.

341. Diseases of the Body of the Uterus

(*Simple Endometritis; Chronic Endometritis; Exfoliative Endometritis; Chronic Metritis*)

Causes. These are retention of septic material, extension of cervical disease, displacements, subinvolution, and laceration of the cervix. Affections of the uterus are often accompanied by ovarian and tubal disease.

Symptoms. The menstrual period is usually longer and the flow more profuse. Hemorrhage may be intermenstrual. The secretion is thin, purulent and often bloody, and frequently offensive. There may be constant pain which is increased by long standing, and by the occurrence of the menses. General debility is often pronounced and may be accompanied by nervous affections and mental depression. Sterility or a tendency to abortion may exist.

Physical examination shows enlarged uterus and tenderness of the fundus. The external os is patulous when there is cervical disease; the external os, cervical canal and internal os when corporeal disease is present. If exfoliative endometritis exists the diagnosis is made from the characteristic membrane.

Treatment. For a simple recent endometritis the sedative action of bipolar faradic applications is efficacious, and in young women external application of the galvanic is often adequate. Begin the treatment of chronic cases by vaginal faradic sedative applications, until sensitiveness of the structures is removed, then attack the disease by intrauterine galvanization. If cauterization of the endometrium is intended, or deep interpolar electrolytic action is desirable, use the platinum electrode, positive pole, with the high dosage of

from thirty to one hundred mil. for seances lasting from five to ten minutes.

If a germicidal action on the endometrium is required, metallic cataphoresis of zinc, copper, or of these amalgamated with mercury, with medium dosage of ten to fifty milliamperes, and during seances of ten to fifteen minutes, can be employed. Negative cataphoresis of iodine is useful. The dosage is important, and small currents are often very effective. Sedation, regulation of the pelvic circulation, stimulating muscular contractions, cauterization of the endometrium, electrolysis of the deeper tissues, or the germicidal effect of metal or iodine cataphoresis may one or all be indicated.

When there is hemorrhage the positive pole, thirty to 100 milliamperes—*section-application if necessary*—is effectual. Subinvolution is quickly reduced by electric treatment, the best method being intrauterine positive galvanization, aided by faradic muscular stimulation. If sepsis exists mercurial cataphoresis is the proper application.

When there is a hyperplasia with degeneration of muscular tissue the negative pole ought to be selected, alternating with faradic stimulation. When the secretion is thick and tenacious it may be thinned by the action of the negative pole, and subsequently checked by positive polar applications.

Atrophy of the uterus with premature menopause calls for the negative current. Massey recommends zinc-mercury cataphoresis.

When laceration of the cervix exists it may be advisable to repair it. The surgical operation, however, often fails to remove the symptoms, while with or without repair electricity will produce a symptomatic cure.

Comparison of the following cases is instructive:

Mrs. J., age 39 years, had been operated on for lacerated cervix. She had been suffering from headaches, backaches, and pain and a feeling of heaviness in lower extremities. With the exception of being "lighter on her feet" there was no amelioration of the symptoms after the operation. Four years afterward I was called to see her and found her miscarrying at the third month. She had had irregular pains for three weeks with considerable hemorrhage. The uterine cavity was emptied and everything went well. About six weeks after this she consulted me at my office on account of excessive and prolonged menstruation. Examination showed the cavity of the uterus to be three and three-quarters inches in length, and escaping from the os was a profuse sanguineous discharge. She complained of headache and backache.

Positive intrauterine galvanization was applied, and as she tolerated the current well it was allowed to reach seventy-five milliamperes. During the next three weeks she received eight such applications, generally succeeded by the slowly interrupted induced current. The menstruation then due was normal, and at the succeeding visit the measurements of the uterus were also normal. The patient stated that she felt better than she had for four years. Irregular treatment was given for two months more, when she was dismissed as cured.

Mrs. R., age 28 years, had four children. After her last confinement she had felt miserable, with pain and weakness of back, pain over bladder and ovaries, and headache. One year subsequent to this confinement she had a miscarriage induced by her condition. When the menses next appeared she flowed for two weeks,

and for this she consulted me at my office. Examination showed a unilateral laceration of the cervix involving the whole of the intravaginal portion. The ovaries and tubes were tender and congested, the uterus enlarged and giving exit to a bloody discharge. I gave her a positive intrauterine galvanic application of thirty mil. for ten minutes. Next day the application was increased to seventy-five mil. The applications were then repeated every second day for the next week, and then twice a week until next menstruation, which was profuse and lasted eight days. During next month she received six intrauterine galvanic applications, alternating with the slowly interrupted induced current of quantity. The menstrual flow then became normal, the tenderness of the ovaries and tubes disappeared, the uterus was normal in size, and the patient felt better than she had for two years. She has since borne two children at full term, and feels comfortable and well.

In comparing these two cases it is found that both had laceration of cervix. No 1 was operated on; No. 2 was not; both continued equally to suffer. Both miscarried. Both were ultimately relieved by electrical treatment. The author is not to be understood as advocating surgical non-interference in such cases; but surgeons who operate for the purpose of relieving certain symptoms and fail, should understand that there is an infallible agent in electricity for accomplishing symptomatic cures.

The comparison also proves that the laceration does not directly cause pain, but may set up other conditions which produce the pain, and although the first cause be removed the sequential pathological conditions may remain; further the electrical current is capable of removing sequential pathological conditions and symp-

toms, and by strengthening the parts it enables them to resist the encroachment of subsequent disease.

An important consideration in connection with pelvic pathological conditions in which cervical laceration is a prominent feature, is that when the latter takes place the parts are weakened and enlarged by pregnancy. The employment of electricity so as to bring about a proper involution will render the laceration harmless; this I have often demonstrated in extreme cases.

342. Diseases of the Fallopian Tubes

(*Metrosalpingitis; Salpingitis; Purulent Salpingitis; Pyosalpinx; Hydrosalpinx; Hematosalpinx*)

Symptoms and Diagnosis. The diagnosis of disease of the Fallopian tubes sometimes cannot be made, except by exploratory incision. Continuous pain is generally present, referred to the ovarian region, and is increased on standing. The pain is also increased during menstruation, and by coitus. Menorrhagia may be present.

Causes. Miscarriage and gonorrhea are the most frequent causes.

Treatmeut. Without in any way endangering the patient, tentative application of electricity may be tried, and in a fair proportion of the cases wonderful results ensue.

The high tension faradic current, intravaginally applied, and with a strength so that the patient just feels the current-sensation, will often effect a cure. The patient is apt to feel dizzy, "queer" immediately after the application; this should be predicted, and explained beforehand. This condition is often followed

by improvement which induces the patient to come again for treatment.

When the endometrium is diseased it should be treated: By positive galvanization if inflamed; by negative galvanization if drainage is required. In all cases employ minute dosage. A few treatments will enable an experienced electro-therapeutist to make a differential diagnosis, which will be valuable in pointing out the indications for further treatment.

343. Oophoritis

Causes. Extension of inflammation through the Fallopian tube, septic infection by the lymphatics of the uterus, gonorrhea, suppression of menstruation, and acute rheumatism are the principal causes.

Symptoms. Bimanual examination reveals the ovary enlarged and tender. Pain is present and is increased by the erect position, by exercise, coitus and defecation. Pain is increased during the menstrual flow, especially immediately before and at its commencement, and may be relieved by profuse flowing. Loss of appetite, vomiting, and mental depression may be accompaniments. Oophoritis may cause sterility.

Treatment. Vaginal bipolar or monopolar faradization, high tension and rapid vibration daily applied is of great service. The rapid vibrations render the nerve incapable of conducting painful impressions, and there is a resulting muscular relaxation and lessened tension. After the sensitiveness to pressure has been relieved the galvanic current may be used, employing small dosage at first, but gradually increasing. Coincidently with electric treatment there should be given attention to the bowels, and to the removal of other

causes or accompanying troubles. If the ovary is prolapsed support it with a tampon.

When atrophy has taken place apply the negative as the active pole. If hyperplasia exists the positive pole is indicated. This pole is also indicated when there is much sensitiveness; the negative is the pole to be used for the removal of adhesions and chronic hyperplasia when there is not much tenderness.

Even when degeneration has taken place much can be done with electricity. Place the positive pole of the galvanic current in the vagina against the ovary, and the negative indifferently. Commence with small currents as tolerated, and raise until 100 milliamperes are borne. Use faradic bipolar sedation, in alternation with the galvanic, if necessary.

344. UTERINE DISPLACEMENTS

(Anteversion; Anteflexion; Retroversion; Retroflexion; Prolapse)

In the treatment of displacements of the uterus it is important to ascertain the causes and the accompanying lesions, the removal of these being the first step in successful treatment. The causes of displacement are congestion, hyperplasia, and laceration or atrophy of the supports. Parturition is a frequent initiatory cause. After miscarriage or labor there may be unequal involution causing displacement. Laceration of the perineum, by impairing the pelvic floor and allowing the vaginal wall to prolapse, results in displacement. Inflammatory adhesions may draw the uterus out of position. Passive congestion from impaired circulation is often a cause. The uterus may be fixed in its abnormal position by inflammatory exudation.

Symptoms. These are backache, headache on summit or occiput, and weight or a dragging sensation in the pelvis. Ovarian pain may be present. Irritability of the bladder and constipation are frequently associated.

Treatment. The successful use of electricity in displacement rests on its power of sedation to painful and inflammatory conditions, on its liquefying and absorbing exudations, and on its stimulating action on muscular tissue. By its electrolytic, cataphoretic and electrotonic properties these results are accomplished. Scientifically-applied currents must of necessity vary as to the method according to the symptoms present, and to obtain the desired degree of success requires a special knowledge of gynecological pathology added to a special knowledge of electro-therapy.

It is essential for the success of the treatment that at its commencement particular attention be given to the hyperplasia, or to its causes, which may be an endometritis or other coexisting inflammation. The distress and painful symptoms which the patient complains of will thus be relieved. At the same time a concurrent treatment may be instituted to strengthen the muscular supports. A moment's reflection will at once convince anyone that merely replacing the uterus by means of a pessary will tend to add to the insufficiency of the muscular structures by relieving them of function, whereas the reverse is the case by employing electric gymnastic treatment. The one tends to bring about a physiologic state, the other, by causing atrophy of the muscular layer of the vagina and round ligaments, hastens fatty degeneration, thus tending to render the primary lesions permanently incurable.

Painful and inflammatory conditions need to be subdued by vaginal applications, using the positive pole of the galvanic current or the high tension faradic current—monopolar or bipolar applications. If the uterus is fixed in its abnormal position vaginal applications should be made until a certain degree of mobility is obtained, when the negative pole for its power of softening exudations and promoting absorption is indicated. After there is a certain degree of mobility the intra-uterine method may be employed, but this will vary as to dosage, polarity, and length of seance, according to the sensitiveness of the endometrium, and according to the existence or non-existence of an endometritis. Carefully applied positive currents of small amperage will soon overcome the sensitiveness of the membrane, and then the negative pole can be used for its liquefying effects. Vaginal treatment can be interspersed, if necessary, with intrauterine applications, thus correcting any unpleasant results of treatment by the latter method. When there are no acute symptoms, or when those present have been subdued, for the breaking up of the adhesions negative electrolysis, assisted by the slowly interrupted faradic current, should be resorted to. Contractions and relaxations, say sixty times a minute, produced by the coarse current on the pelvic muscular tissue, have a powerful influence in breaking up the adhesions; the whole pelvis is seen to vibrate under current influence. However, caution must be had in using this current, for if there exist any pelvic acute inflammatory action harm may ensue.

A thick tenacious uterine secretion calls for the liquefying action of negative galvanization even if positive polar sedation were otherwise indicated, in which event the current should be small. The catarrhal

secretion being thinned, the endometrium cleansed, and the canal rendered patulous for drainage by cathodal applications, the anode will be more effectively applied.

In uncomplicated cases of displacements, or when all complications have been removed, and the uterus replaced, the problem to be solved is how to strengthen the supports so as to enable the organ to maintain its natural position. As an aid to the electrical treatment the temporary use of the pessary may be called for; or cotton or wool tampons may be employed. In some cases electrical treatment alone is effective. If a pessary is used it should be dispensed with as soon as possible, remembering always that electrical stimulation of the muscular structure is the key to success. As an aid to electrical treatment practicing the knee-chest position will be of immense advantage to the patient in prolapsus and retrodisplacements, and she ought to be instructed to do so frequently.

For the purpose of restoring the muscular structure to its natural vigor the faradic current is the best. For this purpose monopolar or bipolar intravaginal or intrauterine applications are the best methods. The weakened part of the uterine muscular structure should receive attention and the poles placed so as to allow the current to pass through that portion. Thus in retrodisplacements the external electrode should be placed on the abdomen; and in antedisplacements on the back, or in the rectum; the active pole being intrauterine in position if possible; if not its position should be intravaginal, on the opposite side of the cervix to the external electrode; or the intrauterine bipolar electrode may be used. Tripier's method of introducing a pole into the bladder in retrodisplacements is not altogether

desirable, nor do the advantages of the method balance the disadvantages; it may however be resorted to in stubborn cases.

An important consideration is the effect of the length of the seance on muscular reactions. The muscular fibers should not be exhausted by the duration of the application. *Three minutes* is sufficient time to subject a muscle to vigorous contractions for the purpose of nutritional stimulation. In cases of slight displacement with constriction of the internal os the author favors galvanic negative applications, small dosage of three to ten milliamperes, and short seances of three to ten minutes. An important object is to keep the os patent, so that pregnancy may occur, if this is desirable.

345. Fibroid Tumors

Treatment. The pathology of tumors has already been considered. As lowered vitality of the uterine structure is a factor in the causality of the neoplastic growth, and as all vital forces are akin to, and interchangeable with electric force, the latter standing in somewhat the same relation to the former as inorganic to organic chemical processes, being the same in principle but simpler in character, there can be no doubt but that electrical applications have a modifying influence on vital processes. Let us consider: Electricity acts on such tissues as fibrous, and in general on proliferating cells, merely by electrolysis; whilst on the nerves and muscles it imparts, in addition to electrolytic action, a physiological stimulus in accordance with their differentiated properties. Electricity, therefore, by its electrolytic action inhibits the proliferating power of the tumor-cell while at the same time it stimulates the

physiological processes of normal muscular and nerve tissue, lessening the aggressiveness of the former and increasing the resisting power of the latter, thus tending to re-establish the healthy equilibrium.

Electricity also stimulates the absorbents, thus keeping step, in producing elimination of the waste products, with the electrolytic disintegration set up in the tumor. Furthermore, its constrictive influence on the muscular coats of the arterioles within the tumor-mass, and the contraction of the blood vessels at the pedicle, thus restricting its main supply by partial ligation, starves the neoplasm by controlling the lymph or blood stream on which it feeds. When applied to tumor-growths electricity increases the arterial tension, increases the blood pressure, but lessens the total quantity of blood supply, thus producing temperature and pressure changes approaching normal circulatory conditions. It is apparent that the intrauterine method of application is the most effective. This method places the densest part of the current at the pedicle of the tumor, where a powerful effect on the circulation is needed. The shrinkage of the mass soon follows the initiation of treatment; and relief of the nerves from pressure, and the reduction of the inflammatory processes render a welcome symptomatic improvement. However, the whole tumor ought to be brought under the influence of the current: Thus each cell is an electrolyte, each fiber is stimulated physiologically, each arteriole contracts, blood pressure throughout the mass is raised, metabolism is changed, a more intense anabolism is promoted, a destructive katabolism is initiated, and the field cleared of the katabolites by the stimulation of the lymphatics. The summation being that a degenerative cell is torn apart;

and a normal cell is built up, by increased pressure and by ions produced by electric and nerve action. Furthermore, the direction of osmosis may be changed, and the neoplasm deprived of the essential nutritive elements for segmentation.

Hemorrhage exists in the majority of cases owing to diseased conditions of the endometrium and the increased supply of the blood. This is more common in the submucous variety and in myomata than in fibromata. Its control is effected by cauterization of the endometrium by intrauterine galvanization, especially by the sectional method of Apostoli, or by mercurial cataphoresis.

All fibroid tumors situated within the pelvis yield symptomatically, and to a large extent anatomically to electric treatment. The subperitoneal variety when confined to Douglas's cul-de-sac yields to vaginal puncture, and to simple intravaginal applications, the latter being preferable. Intrauterine applications when available are also effective. The subperitoneal variety when large, and not within the pelvic cavity, has been subjected to abdominal puncture with success, but generally these cases should be referred to the surgeon.

If a contraindication to laparotomy should exist abdomino-vaginal applications should be tried.

Submucous cases when not too large are suitable for electric treatment, which should be stimulation of the normal pelvic elements so that they resist further encroachment. Under electric treatment they become more pedunculated, and if surgical interference is found necessary are more easily dealt with.

The intramural or interstitial fibroids are the class most amenable to electric treatment, which is soon fol-

lowed by symptomatic cure and considerable diminution in size of the tumor.

Contraindications. Pelvic pus cavities absolutely contraindicate electric treatment. Acute inflammatory action should first be subdued by vaginal treatment before intrauterine treatment is undertaken. Fibrocystic tumors of the ovaries or tubes are not benefited by current-applications although no post operative disturbance is set up, and the same may be said of fibroids complicated with ascites; and also of soft gelatinous fibroids where the muscular tissue has nearly disappeared.

The experienced operator, carefully approaching his case with low intensities, will be able to discover these contraindications, and at the same time differentially diagnosticate the accompanying conditions, without disadvantage to the patient. Some cases, contrary to expectation, will give favorable results—ascites may be absorbed, inflammatory action allayed, a fibro-cyst, a pus cavity or a periuterine lesion diagnosed.

The faradic current, especially of high tension with rapid vibration, is useful in allaying irritation, either of a hysterical character or when set up by galvanic applications. The slowly interrupted induced current is useful in stimulating normal muscular fibers. Faradization may be employed with advantage in alternate seances with galvanization, and its action is of the greatest importance. Practically being devoid of, or having slight electrolytic action, it nevertheless does subsidiary but none the less essential work in stimulating the lymphatics, promoting the absorption of electrolytic products, allaying nervous irritability, and in general doing preparatory work for the next galvanic seance.

Results of Electric Treatment. Apostoli treated several hundred cases and reported permanent benefit in ninety-five per cent of his cases. Keith, formerly of Edinburgh, afterwards of London, reported even better results than Apostoli.

G. B. Massey reported over fifty cases treated by electricity, which he divided into five classes as follows:

1. Cases of complete anatomical and symptomatic cure, 7.
2. Cases of partial anatomical and complete symptomatic cure, 22.
3. Cases of symptomatic cure without anatomical change, 7.
4. Cases of neither anatomical nor symptomatic change, 2.
5. Cases made worse by treatment, 1.

I. R. Kellogg reported 60 cases, as follows:

1. Complete cure, 14.
2. Diminished in size and symptomatically cured, 17.
3. Size not diminished but symptomatically cured, 11.
4. Size not diminished and other symptoms but slightly relieved, 5.
5. Cases in which electricity was not fairly tried, 4.

He also reported three cases not benefited, and one case made worse.

The author reports four cases, all of which were symptomatically cured, and in two the tumor entirely disappeared.

Electricity may be employed in a large variety of cases of fibroid tumors with benefit, and cases where operative measures are necessary no harm is done by its employment. The surgical operation, however,

should not be delayed when it becomes evident that relief cannot be obtained by other means.

346. *Operative Methods.* The same antiseptic precautions should be taken as before a surgical operation. Specific vaginitis or urethritis should be particularly guarded against. A carefully administered vaginal injection containing the sublimate should be given the patient. The sound should be held in the flame of an alcohol lamp, or other suitable antiseptic measures taken, before introduction into the uterine cavity.

Intrauterine Applications. A sterilized platinum sound, properly insulated and fixed solidly in its handle is carefully and gently introduced into the uterine cavity. No force should be used. If the patient complains retreat slightly, and again advance gently. Displacement of the uterus, atresia, congestion of the mucous membrane or a sinuous path may interfere with its introduction; a nervous spasm may exist which with patience is soon overcome. The negative pole can be applied and will assist in effecting an entrance. If possible it is best to introduce the intrauterine sound without a speculum. When the sound is introduced as far as possible, the sheath is pushed forward until in contact with the cervix.

The sectional method of Apostoli is accomplished by having a comparatively small portion of the electrode uncovered. One part of the endometrium is dealt with, then the instrument is withdrawn and placed in contact with the contiguous section. The only advantage of the method is that a smaller current is required to cauterize the endometrium.

Galvano-Puncture. The author advises this method of opertating to be left to the specialist in gyneco-

logical electro-therapy. It is unnecessary, therefore, to describe it in this work.

Intravaginal Applications. The intravaginal method will be found effective in some cases, and should be tried when the intrauterine method is contraindicated or is not available. It is a good plan to initiate treatment in all cases by this method. A ball electrode, made of carbon or other suitable material, covered with absorbent cotton and well moistened, is introduced into the vagina and pressed against the most prominent part of the tumor.

347. *Dosage.* Electric applications to fibroid tumors range from 50 to 250 milliamperes. The author's experience leads him to believe that very large amperage is not necessary. Two of his cases yielded to intravaginal treatment with an average dosage of 100 milliamperes. In a case of interstitial fibroid the patient had two seances at which 240 milliamperes were used, otherwise the average amount was about 100 milliamperes.

Large amperage is said to deal the cell an electric blow, and this may be true. It is similar to the blow of shock. Not only are the more sensitive atoms of the cell-molecule electrolyzed, but the stable base is shattered beyond recovery. The resulting ions combining to form simpler compounds are absorbed and eliminated.

The sensitiveness of the patient to the treatment as shown by post operative reactions will guide the operator to safe dosage in future applications. Rest in bed for a day or two after the use of large amperage is advisable, and rest for a short period following all seances should be insisted on. The patient should be advised of post operative disturbance, otherwise she

may be discouraged and lose confidence in the treatment.

Polar Differentiation. In general when there is hemorrhage, and the tumor a fibro-myoma, soft in character, the positive is indicated as the active pole; on the other hand when there exists a growth of firm texture, with no hemorrhage, the negative is the better pole. Again there are cases where the poles can be used alternately with advantage, the one correcting or preventing the unpleasant results of the other. The judgment of the operator should be such as to enable him to differentiate polar action, and to meet the exigencies of individual cases.

Menorrhagia and Metrorrhagia

348. *Causes.* Amongst these are constipation; deficient nutrition; anemia and its concomitants. The local causes are fungous endometritis, hypertrophy, impaired pelvic circulation, lacerated cervix, subinvolution, retroversion, and prolapsus.

Treatment. The indications are to regulate the circulation and to stimulate the nervous system, especially locally. Galvano-cauterization with positive intrauterine application, or mercurial cataphoresis may be employed. The faradic current may be used alternately with galvanic treatment for its nerve and vascular effects. Vaginal faradization or vaginal positive galvanization will sometimes effect a cure when direct applications to the endometrium aggravate the trouble. A correct diagnosis of cause being made, treatment should be instituted for its removal.

Amenorrhea

349. The causes or accompanying conditions are as follow: Defective development of organs of generation; premature atrophy, or superinvolution; general diseases, as anemia etc.; sedentary habits; malassimilation, insufficiency of food, or excessive development of fat; psychical disturbances as from over-study, insanity, grief, anxiety. Sometimes the causes are not discoverable.

Treatment. Stimulate the pelvic neural, vascular, and glandular systems. See to the general health, and to the habits of the patient.

If the cause is general rather than local, static electricity is excellent—tonic spray to spine and abdomen; or general electrification may be sufficient.

Abdomino-dorsal galvanization, thirty to one hundred milliamperes, or faradization with strong currents is often successful, and should be tried in cases of young unmarried women before resorting to vaginal examination. Spinal galvanization up to twenty milliamperes, and spinal faradization with currents of tension, up to comfortable tolerance are usually beneficial. If these are not successful intrauterine negative applications of the galvanic or faradic currents are indicated. Avoid the use of speculum in virgins if possible. The positive electrode of the faradic may be placed with advantage over the upper spine, or on the breasts; the positive pole of the galvanic should be placed on the abdomen or back. Bipolar faradization with high tension currents, applied to a degree approaching tolerance, is an excellent method for the treatment of amenorrhea.

Vicarious Menstruation

350. Sometimes this takes place as blood, and sometimes as a secretion. It may come from the stomach, lungs, nose, throat, bladder, or anus. It may indicate defective development of the uterus or ovaries. The local electric treatment is the same as in amenorrhea.

Scanty Menstruation

351. *Causes.* The same as in amenorrhea. Individual peculiarity causes variation in the amount and length of period. It is often associated with neurasthenia. The patient may be heavy or slight in build. Often a hyperirritability of the nerves coexists.

Treatment. Allay irritability of nervous system by a current of high tension with rapid vibration. Attract blood to the pelvic organs by applications of the galvanic current with the negative placed over hypogastrium and the positive indifferently; or make a negative intravaginal or intrauterine application with moderate dosage of from ten to thirty milliamperes. Alternate galvanic and faradic applications are useful. Repeat two or three times a week during the intermenstrual period. Bipolar faradization, high tension current, is also useful.

Dysmenorrhea

352. The following conditions may coexist or be the cause of the disturbance: Chlorosis, a neurotic constitution; spinal or other neuralgias; constipation, hepatic torpidity; stenosis or flexion giving rise to the idea of mechanical obstruction; hyperæsthesia of the endometrium, especially at the inner os; endometritis, parame-

tritis, perimetritis; spasm of the uterine muscle set up by reflex causes, such as over sensitiveness of the lining membrane; or membranous endometritis with profuse or scanty menstruation. Dysmenorrhea may be complicated with neoplasms, pelvic deposits, abscesses, etc., which require special consideration.

Treatment. When the cause is non-pelvic, whether constitutional or neural, static electricity, stimulating or sedative, meets the indications. High tension faradic applications have excellent tonic effect. Spinal or abdomino-dorsal galvanization is sometimes effective.

When the cause is ovarian, vaginal faradization or galvanization will often relieve. The majority of cases require intrauterine treatment by the galvanic current, which may be advantageously followed by high tension faradization.

353. The following is a typical case: Miss B. had been menstruating for six years, during three of which she had suffered great pain, being confined to the house and even to bed for two or three days at each period. The flow was scanty.

Abdomino-dorsal high tension faradization was applied three times a week for one month without improvement. During next intermenstrual period intrauterine negative galvanization was resorted to. Placing the positive electrode over the abdomen, the intrauterine electrode was pressed gently against the os, which it barely entered; then carefully turning on the current it was gradually raised until marking ten milliamperes. Continuing the pressure the electrode slowly passed to the internal os. At this point, the patient complaining of pain, the controller was slowly reversed to zero, the instrument withdrawn, and a tampon of boroglycerine inserted. Two days afterwards, at the

next sitting, the electrode entered freely to the internal os, and the current being made and raised gradually to fifteen milliamperes, the electrode with slight pressure reached the fundus.

The intrauterine applications were made twice a week, alternating with vaginal bipolar high tension faradization, up to next menstrual period. Afterwards irregularly for one month longer. The menses were then more profuse and absolutely without pain.

Sterility

354. *Causes.* Amongst these are stenosis and flexion of the uterine canal, perhaps not so frequently as they are ascribed to be; abnormal secretion of utero-tubal canal; impairment of nutrition of the endometrium; ovarian inactivity; various organic pelvic diseases, as tumors, inflammatory exudations, etc.

Treatment. Electrical abdomino-vaginal applications will correct the circulation and improve the nutrition of the parts. The uterine secretion can be increased by negative, or decreased by the positive polar intrauterine action, and at the same time altered in quality. Ovarian stimulation can be effected by placing the negative pole over the ovaries, the other pole indifferently.

Negative intrauterine galvanic applications, small dosage—three to fifteen milliamperes—and of short duration—three to ten minutes—have been successful in a large number of cases treated by the author. Where no apparent cause exists the fault probably rests with the endometrium—in osmotic conditions affecting the nutrition of the ovum. It is in this class of cases that intrauterine galvanic negative applications, with delicate stimulation, and short seances, are deserv-

ing of a trial. The author adopts the following plan: The current is applied twice a week for two or three months; then the applications are omitted for the succeeding two or three months; then treatment is resumed, and so on in alternation. The purpose of the plan of treatment is explained to the patient, she remains under supervision, and retains the hope of a successful result.

Women that have borne children to one man have been barren to another. Giving full weight to the possibility of the man being always potent, there remains the probability that there is an absence of potential coefficiency on the part of ova and spermatozoa (§ 237), in some of these cases.

ADDENDA

Sedation and Inhibition of Nerve Action

355. In considering the results of electric stimulation of the pneumogastric on the heart, we formulated the conception that inhibition is caused by an efferent impulse through an afferent nerve, and without doubt this concept is correct as regards electric stimulation of the vagi. The subject, however, broadens, and includes modifications of the impulses of a neural pathway by extraneous vibrations from by-paths; and also the actions of medicinal agents and other potentials on nerve terminals. The differential actions of extrinsic potentials on the nerves have been already tabulated. It has been pointed out that the action of chloroform on the endocardiac nerve-terminals is identical with that produced on the same terminals by stimulation of a cut pneumogastric. It is the propagation of nerve-action from neurone to neurone in a pathway, and its modifications by vicarious impulses from by-paths, that is to be further considered here.

The primary considerations are these:

1. An electro-negative nerve unit when at rest.

2. A negative leading off terminal and a positive distal terminal of the neurone when in action.

3. A positive physiologic initiatory stimulus.

4. It follows that the application of a negative (static) force to a nerve terminal is sedative, inhibitory, or productive of reverse action.

It is to be kept in mind that the potential at a distal neurone-terminal is static in character, that is, the force does not move from the exciting terminal, except as a wave, thus differing from the potential of an electric current. Also it is to be remembered that each vibration consists of a complete polarization and depolarization of the neuromere, and hence of the neurone (§ 269). We are led to postulate: That in physiologic action no neurone has a negative distal terminal, consequently under normal conditions no neurone acts on another by a negative potential; and further, under the same conditions, no neurone exercises an inhibitory action on another neurone as chloroform and other negative agents do on nerve terminals. A branch-neurone to a nerve pathway possibly: (1) May produce a disturbance of rhythm by the character of its vibrations, such as is shown by psychic influence on cardiac action. (2) It may have vibratory frequencies which cannot be responded to (the appreciation of the various sounds and colors shows this differentiated capacity). (3) It may take possession of an induced field of an initiatory neuromere (in a similar manner to the action of high current-frequencies) and thus inhibit the function of the neurone. However (4) the exciting potential physiologically is always positive (Fig. 92).

Nevertheless, physiologic units are capable of having positive leading off points, and sequentially negative exciting terminals: A muscle stimulated from its center becomes positive at one end and negative at the other, and must have a positive and a negative leading

off point. A nerve has extra polar currents in both directions, and therefore the impulse wave travels in both ways, and consequently must have one exciting negative terminal.

It is evident that pathologically inhibition may take place in several ways: (1) By reverse initiatory action (as by electric stimulation of a vagus, or by the action of chloroform in the blood, taking possession of an initiatory field such as the endocardium), thus blocking the natural stimulus, and even propagating a reverse action in other neurones (Fig. 121); (2) by very rapid frequencies a vicarious force may possess the small molecules of the induced field of the initiatory neuromere, thus causing a block; (3) a terminal of a by-path neurone (a commissural fiber) may block normal or produce reverse action by acting on the adjoining distal terminal at a reflex center in a pathway or cycle, whilst introducing vicarious action through an initiatory terminal, as in volitional paralysis with spastic muscles (Fig. 125). Thus as indicated in Fig. 126 the action of the fiber, C A, is blocked, whilst that of the fiber, D A, is stimulated by the vibrations of the fiber, B A.

It is apparent that a general formula of inhibition is impossible as the fundamental factors are different. Tabulation of the conditions of stimulation and sedation of nerve-terminals by extrinsic forces has been made (§ 159); and the differential actions of one neurone on another conform to this tabulation and to the general law of attraction and repulsion.

RADIO-ACTIVITY

The following facts relative to radio-active substances

were gleaned from various sources after this work had gone to press:*

Radium exists in the form of small white crystals, which may be crushed into a white powder looking like ordinary salt. Although considered a metal, it has not been secured in the metallic form, but usually as a chloride or bromide. For convenience, it is kept in sealed glass tubes covered with a fold of lead for the purpose of protection, as the concentrated rays are destructive to the tissues when applied for some time. The tube in which it is kept, owing to its radiations, has a temperature one and one-half degrees above that of the surrounding atmosphere. A sample of 9/10 grain emitted light sufficient to read by when held near the printed page.

Professor Curie estimated that a decigramme of radium would sufficiently illuminate a square decimeter of surface for reading purposes; or a kilogram, a room thirty feet square with a mild radiance. The light would be intensified by the induction of screens of zinc sulphide, the radium emanations throwing them into a brilliant phosphorescence. A large quantity of radium in a room will make radio-active the walls, furniture and the clothing of everyone present. Workers with the substance have the greatest difficulty in keeping their instruments free from radio-activity.

Professor Curie demonstrated that radium gives off emanations distinct from its heat and light radiations. The radiant matter settling upon all surrounding objects confers upon them radio-active properties. Powdered zinc sulphide seems to be the most responsive to

* "Radium and other Radio-active Substances," by William J. Hammer. "The Wonders of Radium," by Cleveland Moffatt, *McClure's Magazine, November, 1903.*

the transforming influence. Glass appears to offer resistance to the passage of the emanations, whereas the rays of light and heat from radium freely pass through this material. Rutherford has shown that similar emanations issue from thorium. Rutherford and Soddy have succeeded in condensing the radiating matter at the temperature of liquid air. Sir William Crookes has devised an instrument which he has named the spinthariscope, and by which the emanations from radium may be observed.

The duration of radio-activity maintained by other substances induced by radium appears to vary according to the character of the substance, and the environing conditions. M. and Mme. Curie have made experiments on copper, aluminium, lead, rubber, wax, celluloid, paraffin and numerous other substances. From these investigations they arrived at the following conclusions: That all substances can be rendered radioactive; and that the induced radio-activity is retained longer when protected, as by a sealed glass tube. When guarded induced activity diminishes one-half in four days; when not guarded it diminishes one-half every twenty-eight minutes.

Radium changes the color of phosphorus from yellow to red. When it is dissolved in water hydrogen is thrown off by molecular disintegration, but it is not known what combinations the oxygen forms. Radium gives a violet or brownish tint to a glass vessel, and the color remains permanent unless the glass is heated red-hot. When exposed to radium diamonds burst into a brilliant phosphorescence, but upon false stones there is little or no effect. When radium is exposed to a temperature of 1,000 degrees (Cent.), or when kept in

a vacuum for some time, it loses its peculiar properties. After a lapse of time it recovers its full energy.

The standard of radio-activity is the original radiations emanating from uranium as discovered by Becquerel. Thus when a substance is said to have a radio-activity of 300, it means that in comparison to the standard it is 300 times stronger.

Polonium apparently loses its radio-active power. Elster states that when placed in a vacuum its rays may be deviated by a magnet even to a greater extent than the rays from radium. Crookes has demonstrated that polonium rays do not pass through glass as do the rays from radium. They are also differentiated from radium rays in being absorbed by quartz and mica. The actinium rays are deviable. Professor Curie states that radium, actinium and polonium possess activity one million times that of uranium.

Radium has the property of rendering the liquids of the eye-ball self-luminous, or phosphorescent, and when in this state they produce a sensation of light. It will produce this effect either by being placed over the eye, or being placed over the temple. This property may have a diagnostic value in certain diseases of the eye by showing whether or not the optic nerve remains intact.

Radium is destructive to organic life exposed for some time to its energies. Mice, rabbits, guinea-pigs and other animals have been killed by being exposed to its emanations or rays. Probably all forms of life would eventually succumb to the destructive force of radium in great intensities. In other instances organic development has been arrested; in still others the species has been modified by prolonged exposure.

Radium seems to have the property of modifying organic molecules or cells, and good results have been obtained in the treatment of lupus by the application of the rays. Indifferent bodies rendered radio-active may be employed in the treatment of such cases. It appears that under certain conditions radium possesses bactericidal properties.

Rutherford, the Curies, Becquerel and others have demonstrated that there are three distinct types of rays emanating from radium. These have been designated as "α," "β," and "γ" Rays.

Rays "α"—These constitute the major portion of the energy and have certain common properties with Roentgen rays. They have been considered as non-deviable and have the property of producing ionization of the gas, observed by investigators under experimental conditions. Rutherford has shown that in a powerful magnetic field forty-five per cent of "α" rays are deflected. He states that all radio-active substances, including polonium, give out "α" rays.

Rays "β" are longer and more penetrative than rays, "α," and have characteristics identical with those of the cathode rays. They are deflected by a magnet, discharge electrified bodies by ionization of the elements of the air, and possess the properties in general of the cathode rays. M. Villard in 1899 demonstrated that the cathode rays are negatively electrified fragments of the atoms of residual gas. They are supposed by J. J. Thomson to have a speed approximating 70,000 miles an hour.

Rays "γ" possess the greatest penetrating power, and are capable of producing radio-activity through the air at a distance of four feet, or more. Rutherford showed the relative penetrating power, with a loss of

half their intensity, of the different types of rays to be as follows:

Rays "α"	a thickness of aluminum of					.0005 C.M.
Rays "β"	"	"	"	"	"	.05
Rays "γ"	"	"	"	"	"	8.

It has been shown that an object coated with calcium sulphide and exposed to sunlight will phosphoresce for ten hours; and it has been demonstrated that bismuth is rendered radio-active by the action of cathode rays. Either uranium or a substance intimately associated with it (perhaps actinium) is radio-active; and thorium oxide possesses radiating properties, which are next in intensity to those of radium.

Pitchblende or uranite, which contains the largest percentage of radio-active material, is found in Bohemia, Saxony, Cornwall England, and Colorado U. S. Radium, polonium and actinium are supposed to be new elements. Polonium and actinium, however, have not been recovered in sufficient quantities to give a spectrum. It is conceded that radium is elementary, and it is considered as belonging to the metallic class, although it has not been reduced to the elementary form.

It is generally conceded that there is no loss of weight to the substance by means of the emanations, although according to Prof. Curie each gramme of radium emits energy to the extent of 100 small calories per hour; or enough to melt in each hour its own weight in ice. As this energy is carried by radiant matter the loss of material must be considerable. Moreover the radiant particles must be larger than the intermolecular spaces of glass, through which only the "γ" rays pass.

What is the source of this energy? This is the question that is agitating scientists, who admit that no satisfactory theory has been formulated. In discussing this subject in a preceding chapter, the author concluded that the exciting energy is the heat or light of the environment; that the ether is split up as in the thermo-electric cells; that the terminals of the radio-active substance became differential poles; that energy as atomic ether radiates through the atmosphere and neutralizes as in a spark; that associated with this energy a stream of sub-molecules or primary condensations is thrown off from the negative pole; and that these particles are charged negatively as in the cathode rays. Furthermore, that on neutralization, the radiancies are converted into ether pulsations, or waves of light. The conceptions were advanced that the transforming power of radio-active substances resided in the delicate vibratory balance of the molecule; and in the peculiar placement of its constituent groups, which allows a positive group of units to be broken off by the current, and thus become radiant matter.

It was concluded (§ 132) that the cathode rays are positive particles or submolecules charged negatively; that the charge neutralized at the anode, and that the cathode particles or those further reduced became the Roentgen rays; and that the energy on neutralization of the Roentgen particles is transformed into light waves.

It appears that the part of the problem to be now solved is: What is the primary source of the radiant particles or positive submolecules which enables the radio-active substance to preserve its vibratory balance? The author is fully convinced that the loss of one particle of the emanations, without compensating associa-

tion, would be destructive to the vibratory balance of a molecule, and consequently to the efficiency of its radio-activity. Hence it is apparent that some inexhaustible source of supply must be at hand from which the radio-active substance compensates its loss, thus preserving its weight and its intensity of action.

We conclude that rays "α" are the charged particles emanating from the negative poles; that on neutralization of the charge the particles become rays "β"; that when the potentials of the particles are neutralized, ether is set free from their induced fields, and is transformed into light waves (rays "γ"); and although light and heat are initiatory stimuli, they are not the main source of energy.

The conception has been formulated that the vacuum tube is a world in itself, and that the various degrees of decrement of its gas must be represented in the atmosphere of the earth. As ascent is made conditions exist which are similar to the diminishing pressure of the tube. If these conclusions are correct, a study of the various decrements of the Crookes tube will enlighten us as to the conditions of the upper atmosphere.

It has been demonstrated that in a vacuum tube, a particle of matter 1,000th the dimensions of the hydrogen atom exists. We have conceived this particle or submolecule to be identical with the primary condensation of positive quality, or as approaching it in character; and have evolved the law that when molecules are dissociated by decrement of pressure the resultants have dimensions directly proportional to their negative constituent units, and inversely proportional to their positive units. As a result of this law, in a tube of great decrement, a negative molecule about

the ordinary size of gaseous molecules, and a positive molecule of extreme minuteness exist.

Bearing in mind the facts associated with, and the principles involved in decrement of pressure as represented in a vacuum tube, we will consider the conditions which must obtain in various degrees of pressure in the air. Provisionally it may be assumed that the atmosphere consists of oxygen, nitrogen, and the other elements as given by chemical analysis. It must be kept in view that these elements are preponderantly electro-negative; that they repel each other in accordance with the law of forces; that they have intermolecular spaces which are induced fields; and that between the induced fields there are interspaces (§ 29, § 33, Fig. 6). If oxygen molecules are followed upward it will be seen that the interspaces and induced fields enlarge and that such increase is proportional to the height. It is probable that concurrently with the enlargement of the intermolecular spaces the chemic atoms sever their connections, evidently this being a natural line of cleavage. Each oxygen atom then becomes a molecule. The cleavage of the oxygen molecules into two equal parts, however, does not alter the dimensions of the induced fields or interspaces, the sum of the inductive potentials of the two new molecules is equal to the inductive potential of the previous molecule. Neither does this cleavage alter the character of oxygen, as, chemically and electrically, it is the atom of oxygen which acts or is acted upon. At a point probably beyond a decrement at which life is possible the oxygen molecule representing the chemic atom breaks up. The dissociation will be into a very small electro-positive molecule, and into one having dimensions nearly equal to those of the dissociating

molecule, and of electro-negative quality. Each of the nascent molecules will have inductive potentials greater than the one from which they are derived.

What becomes of the nascent molecules, the disintegrated parts of the oxygen atom? The electro-negative one will be in equilibrium. It has weight but it cannot descend, because those molecules which constitute the atmosphere beneath are heavier. Moreover, the negative nascent molecule and those of the atmosphere are mutually repellant, being similar in quality; and their induced fields are impenetrable to each other. Furthermore, the dimensions of the negative nascent molecule are too great for occupancy of the molecular interspaces of the air. Following the electro-negative part of oxygen, or its type, upwards it will be found that it dissociates further with similar results, and this dissociation will go on until the confines of the atmosphere are reached, where a condition of a so-called vacuum exists, that is, to the borderland of the interstellar ether. The electro-negative parts of the dissociated oxygen atom are in states of complete equilibration at the various points of dissociation, and but for physical and extrinsic forces may neither ascend nor descend.

What becomes of the electro-positive submolecule, the dissociated minute chip of positive quality which forms a constituent nucleus of the oxygen atom? If a balloon made of imponderable material could be filled with such chips, it would rise even to the line that demarcates the limits of ponderable matter, just as a balloon filled with hydrogen ascends from the earth's surface. What would take place if the chemical constituency of the atmosphere is correct as stated, and what actually takes place more slowly through the evolution of ages, is descent. Being positive in the

quality of its potential, and opposite to the quality of the molecules of the oxygen and nitrogen of the air, it is attracted by the atmospheric mass below. The minuteness of its dimensions allows it to pass through the molecular interspaces, or through the molecular induced fields the induction of which it neutralizes. Having weight, it filters downward until reaching the earth's surface, and may even penetrate liquids and solids.

Thus in nature's laboratory in the higher atmosphere minute particles are generated, and by filling the interspaces and induced fields of the lower strata they displace the intermolecular ether which is imponderable. They do not combine chemically with the oxygen or nitrogen, owing to these elements being in equilibrium, but remain in the intermolecular spaces where they are not detectable by known chemical means. At the surface of the earth they exert a pressure which, although constituting part of the atmospheric pressure, is capable of acting independently of the latter by reason of the minuteness of the particles and their position in the interspaces. This fact must have an important bearing on the association of the particle with the molecules of radio-active substances. The submolecules occupy a position in this respect distinct from that of any other class of molecules. They are as if placed in innumerable minute tubes the walls of which are the ponderable bodies of oxygen and nitrogen molecules, and the linear dimensions of which must nearly span the earth's atmosphere. Such columns, although intricately zigzag, must exercise immense static pressure when tapped by the vibrations of molecules in a radio-active substance.

A radio-active molecule must possess a constituent group of ultimate units identical to the electro-positive group or chip, dissociated by decrement of atmospheric pressure from an oxygen or nitrogen atom. This group must be the most positive of the constituent groups, as it occupies the positive pole of the molecule when polarized, and the position of the group as a constituent nucleus must have a degree of stability which is overcome by the negative electric current which chips it off under polarization. These are essential factors to the possession of the property of primary radio-activity. It is clear that a line of radio-active molecules placed in position to tap a column of these chips—submolecules or primary condensations—will be in the position of an engine driven by hydrostatic pressure.

There is no doubt but there are many kinds of chip-molecules. Oxygen will furnish one kind at a certain decrement of pressure, and at different atmospheric heights other kinds will be dissociated. Similar results will be derived from nitrogen. Consequently, there are many kinds of radio-active substances. On the other hand the position of the chip in the construction of the molecule will give different degrees of resistances to dissociation. Hence different intensities exist, and hence some radio-active substances require an initiatory stimulus of light or heat.

When the emanations from a radio-active substance are passed through water the hydrogen is dissociated, an oxide of the sub-molecules being apparently formed. It will thus be seen that although the chip-molecules are smaller than hydrogen they are chemically more active. When another substance is subjected to a bombardment of the emanations the latter collect on

the surface of the former with a loose chemical combination, hence induced radio-activity. The emanations, however, may enter into more intimate chemical union with substances, altering the relationship of the ponderable body of the molecule to its vibratory space and thus changing the frequency of the vibrations; thus phosphorus frequencies are changed from yellow to red. These combinations modify the inductive potentials and induced fields of the molecules, and consequently change the relation of the vibratory factors, and the character of their vibrations.

In a preceding chapter it was stated that Roentgen rays were not deflected by a magnet, and this is correct as to ordinary magnets. It appears that rays "β" are deviable by strong magnets, and Roentgen rays should be deviable by strong magnets also. The intense potentials of the particles should respond to strong magnetism irrespective of an electric charge, although when charged they are more susceptible to deviation.

Rays "γ" have the greatest penetrating power because the particles of rays "α" and "β" are evidently too large to pass through some intermolecular spaces. This fact points to the particles of the emanations from radio-active substances being larger than those of Roentgen rays, the latter having greater penetrating power than cathode rays, and evidently losing force when converted into wave-radiations analogous to those of rays "γ".

I. H. Van't Hoff, in 1885, demonstrated that when certain substances were dissolved in water they exerted osmotic pressures equal to their pressures as gases, provided they had the same volume at the same temperature. Thus a given volume of a gas gives the same pressure as that given by an equal volume at an

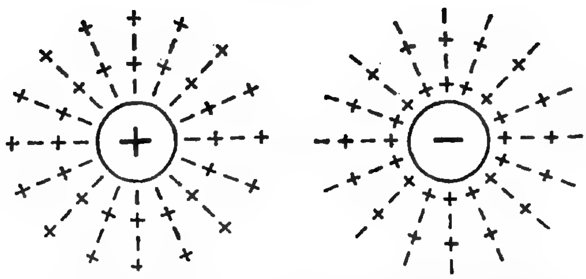
equal temperature of water saturated with the gas. Certain compounds however do not give the pressures which it is calculated they would give as gases. For instance sodium chloride dissolved in water has an osmotic pressure double the calculated pressure. In 1887 Arrhenius showed that compounds creating abnormally high osmotic pressure became conductors of electricity when in solution; and that those having normal osmotic pressure do not conduct electricity when in solution.

These are important facts. When an element or compound is dissolved in water the pressure sends it into the molecular interspaces. If the molecule of the substance is too large to occupy the interspace, and if it is unstable (as chlorine), the pressure dissociates its molecules into ions which are sufficiently small to enter. Chlorine being negative and water being positive, their induced fields will overlap. Consequently the chlorine ions do not interfere with the placement of water molecules. The most important fact shown by the experiments of Van't Hoff is that these ions occupying the interspaces have distinctive pressure from that of the water. Hence chlorine in solution maintains its pressure as in a gaseous state. Evidently this is exactly what we have considered the submolecules or ions of the atmosphere as possessing when their pressure is brought to bear on radio-active substances. When sodium chloride is dissolved in water it is too stable to be broken up, and its molecules too large to enter the interspace, consequently it encroaches on the induced fields of water, which become more distorted. Hence the elasticity of the induced fields of the water must be added to the calculated pressure of the sodium chloride, to the extent of such encroach-

ment. A substance merely occupying the interspaces leaves too much intermolecular space to conduct electricity; whereas a substance filling the interspaces and overlapping or distorting the induced fields conducts electricity as already pointed out when treating of electric conduction.

The conception of a "vibratory balance" has been formulated (§ 1, § 269) and the factors of modification stated. In Fig. 133 a number of molecules are indicated as possessing ponderable bodies with inductive potentials and induced fields qualitatively and quantitatively differentiated. It is observable that silver and copper have very small induced fields and also that they are the very best conductors of electricity, and that they are chemically stable. It is probable that a vibratory balance is best typified in these elements, and as the metals become more or less positive, or change the relationship of the factors of delicate molecular equipoise, they offer more resistance to vibratory stimuli. The oxygen molecule is not an electric conductor, but oxygen chemically combined with hydrogen (H_2O) has that property. Further, when a saline is added to water the latter becomes a better electric conductor. From these and other facts it is evident that a large molecular interspace is detrimental to conduction, and as the space is decreased to a minimum point electric conduction improves. There is evidence however that a further decrease of the intermolecular space increases the resistance. The positive allotropic forms of sulphur and selenium are not as good conductors as silver, and they must have very small intermolecular spaces.

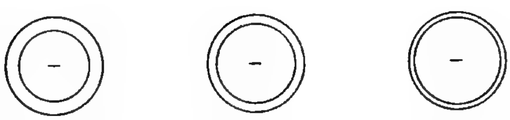
It is possible that the properties of electric conduction and radio-activity have some fundamental characteristics in common. Metallic zinc is not a very good



Electric Inductive (primary), and Induced (secondary) Potentials—Electric Analogues of Molecular Potentials in Equilibrium.

Ether Molecule.

Hydrogen, 2. **Other Molecular Chips (chipchens).**



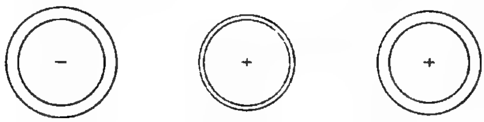
Oxygen 32. **Sulphur 64.** **Selenium 158.**

Fig. 133.

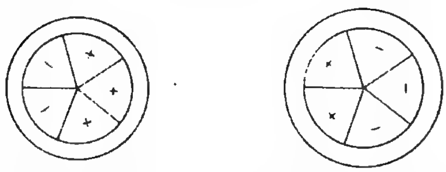
Showing differentiations in the molecular mass (indicated by inner area) relative to the dimensions of the molecular induced field (indicated by outer area). The numbers refer to the molecular weights, or to the atomic weights when the former are not ascertainable. The symbols + and — in the ether molecule denote the entire constituency; in the ponderable molecules and on the charged bodies they indicate the quality of the inductive potentials; and in the induced fields of the charged bodies they indicate the character of electric induction. The dimensions of the molecular mass are estimated on the basis of molecular weight; obviously this does not embrace units immolecularly neutralized. The dimensions of the induced field are directly proportional to the active chemic or inductive potential, but varies according to the material

Carbon (equatorial) 24.

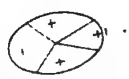
Silver 107. Copper 63. Zinc 64. Potassium 39.



H_2SO_4 98. Zn S 95. K OH 56.



Proteid 16,119. Physiologic Unit *X*.



Radio-Active Molecule, showing Position of Molecular Chip, Negatively Charged.

Fig, 133 (Continued).

within the field. In small induced fields the material (ether) is constant; in larger fields ponderable matter is present, and hence an inconstant specific inductive capacity obtains. The induced areas of hydrogen, oxygen, sulphur, selenium and zinc are equal, being estimated as in a gaseous or volatile state. If isolated the chipchens probably would be found to obey Avogadro's law. The radio-active molecule is shown as constituted of nuclei, the chip at the positive pole being charged negatively. Attraction between the chip and the electric charge being greater than that between the chip and the remainder of the molecule, the chip is torn off by the current. No induced field is shown in the radio-active molecule, as its inductive force is partially or wholly neutralized by the electric charge.

conductor of electricity, it probably has little or no radio-activity; and its molecules have large chemic activity, inductive capacity, and large induced fields. By adding an atom of sulphur to an atom of zinc part of the chemic potential, and the inductive capacity of the zinc is neutralized, hence the induced field is lessened, and the vibratory balance of the molecule is more delicately adjusted. Is not the explanation of the possession of radio-activity by zinc sulphide and other substances to be sought for along these lines? Radium when subjected to a high temperature or placed *in vacuo* loses its peculiar property. That is, the temperature or decrement of pressure increases the dimensions of its molecular interspaces, destroys its vibratory balance and sequentially its radio-active property. When the ether escapes from the intermolecular spaces its vibrations become normal and it resumes radio-activity.

In Fig. 133 different types of molecules are delineated. The ether molecule is shown as consisting of two ultimate units at zero-potential, with no induced field, and devoid of the property of electric conduction. Next to ether molecules and the first in the molecular order of ponderable matter is the hydrogen group, made up of what appears to be submolecular condensations as measured by the standard of equilibrium at the earth's surface. They are chips from larger molecules, and characterized by small ponderable bodies, large inductive potentials, and large induced fields. They are of positive quality, as the negative molecular bodies from which they have been chipped (with the exception of the associates of hydrogen) are found only in the higher atmosphere. Prof. Thomson has applied the term "corpuscle" to certain members of this class.

but this term is applied to the cells of the blood. The author suggests the term *chipchen*. The class probably consists of numerous subtypes varying in potentials, inductive capacities and vibratory frequencies. Hydrogen is a true chip, although it has been recognized as a chemical element. According to its molecular weight it would equilibrate in the higher atmosphere, but its size allows it to fill the interspaces, and its quality to overlap the induced fields of, or combine with larger electro-negative molecules. The term *ion* should be confined in its application to atoms dissociated from their chemical combinations; and the term *chipchen* to the results of dissociation of chemical atoms. Hydrogen is the dividing line and has characteristics belonging to both classes.

The negative group of molecules is represented by oxygen, sulphur and selenium, with varying ponderable bodies, inductive potentials, and induced fields. This group is composed of molecules possessing larger ponderable bodies than the chipchens, (1) because of the law of molecular division as regards positive and negative constituents; and (2) because the smallest electro-negatives are not represented at the earth's surface. Sulphur and selenium are found in allotropic forms. Is not this property a manifestation of chemic union with chip molecules in various proportions, and does not this union take place even to the extent of changing their molecular weights, and the quality of their potential from negative to positive? In the electro-negative forms they are non-conductors of electricity, in the electro-positive form they are conductors. Chemical union may take place between sulphur or selenium and these minute electro-positive particles until their affinities are satisfied, or until a neutral element is

produced. Further chemical association renders them electro-positive.

Carbon represents the equator, with passive chemical potential, with no inductive potential, and no induced field, although its molecular units are taken possession of by extrinsic forces (§ 36, § 37).

The types of positive molecules commence with silver and copper, with large ponderable bodies, small active chemical potentials, small inductive potentials and small induced fields. They approach the true vibratory balance, and offer slight resistance to the electric current. Zinc and potassium are chemically active with larger induced spaces, and offer more resistance to the electric currents.

Compound substances show types of molecules of positive and negative quality. Two types are shown with large inductive potentials and with large induced fields; whilst zinc sulphide is shown as a type of molecules with fine vibratory balance. Lastly the proteid type is indicated as possessing a positive inductive potential and a large induced field; whilst the physiologic unit is shown with very large negative inductive potential and corresponding induced field. The construction of all molecules is on the basis of the ultimate ether units of positivity and negativity indicated by the signs + and — in the ether molecule. The smaller molecules (chipchens) are groups of these units. They are the primary groups of ultimate units. The next in size or the molecules of the so-called chemical elements are composed of groups of the primary groups. The primary groups associate and dissociate without losing their own constructive character. Thus oxygen dissociates in a vacuum tube: (1) Into its chemical atoms, and (2) these into primary groups. It is the chemic

atom and not the molecule that has permanent character. Association takes place in the reverse order, without permanent disturbance. Next the chemical compounds are composed of groups of chemic atoms and on dissociation these groups may be maintained. Thus H_2SO_4 dissociates into $H_2O + SO_3$. In the domain of the organic molecule a still more complex construction exists, and we find larger groups of chemical atoms. Thus the proteid molecule has the biuret, aromatic, and other groups, and these are broken up into smaller groups or end-products. Lastly, the physiologic unit with a complex but unknown constituency may be considered as composed of positive and negative groups. It is probably the limit of molecular association.

When the physiologic unit polarizes the polarization is accompanied by waste-chips or ions knocked off from its molecular poles. When the proteid dissociates it chips. Water is chipped from sulphuric acid, from glucose, and from many other compounds. When the dissociation of simple compounds, as water, is reached chemically elementary chipping has to be considered. The ultimate units of matter must be the ether atoms, although interchange between ether and ponderable matter may not be demonstrable. The ether units are quantitatively and qualitatively definite, and their dimensions are unalterably fixed by the relation of matter and force to space. The fundamental factor of differentiation between units in the ether condition and units of equivalent value possessing ponderable properties must be one of relative placement of, or distance between, neutralizing ultimate quantities. The property of radio-activity belongs to certain substances because their molecules possess constituent nuclei

which by virtue of their volatile character and relative placement are dissociated by the negative electric current, and which are associated from a column of identical chipchens in the atmosphere, the static pressure of the atmospheric column being the main factor of the energy. The radio-active molecule is shown (Fig. 133) as positive without the constituent chipchen, hence the position of the chipchen as a constituent is maintained by the attraction of positives, and by the molecular equilibrium of the radio-active substance; and hence the attraction between the chipchen and negative electricity is greater than that between the chipchen and the other molecular constituents. It must be remembered that there is a potential of concentrativeness and a potential of diffusibility; that the former tends to dissociation and the latter to association. It follows that the larger groups are more unstable and the smaller are more permanent.

Crystallization

The author has suggested that water crystallizes by association of molecules reversely placed (§ 149). This theory is objectionable, as the emission of ether during cooling polarizes the molecules uniformly. It is possible that the molecules of positive potential, such as those of water, may crystallize by association of electro-negative chipchens from oxygen, or by association of ions of oxygen held in solution. It is probable that oxygen is held in solution in water by each atom occupying a molecular interspace, and during the crystallization it furnishes associating molecules either in the ionized state or by being further dissociated as chipchens.

Electric Conduction

Why certain elements are electric conductors and others insulators has not been fundamentally, and hence not satisfactorily, explained. If each of the different elements indicated in Fig. 133 filled a gap in an electric circuit, we would find that there would be about as many different results as there are elements. To be able to refer the variations in the results to their primary causes it is important to bear in mind that all forces react inversely proportional to the square of distance; and also that positive units are concentrative, that negative units are diffusible, and that there is attraction between positives and negatives, as expressed in Fig. 5. If by the law of attraction and repulsion as formulated (§ 1) the multitudinous degrees of intensity of electric conduction, and its manifold phenomena are explainable, conversely the correctness of the formularization is supported.

If the gap be filled with ether (a so-called vacuum), there will be an absolute break in the circuit. According to the law of forces ether is not a conductor of electricity, at least not in the environment of other matter. The ether units neutralizing by maximum contact resist interference as occurring in electric conduction.

If chipchens be placed in the gap they partially arrange themselves into two classes, the negative class going to the positive pole, and the positive to the negative pole of the circuit. Both of these are charged, but the positive elements with their negative charge become the radiant matter, as manifested in the cathode rays.

If the break in the circuit is filled with oxygen, its molecules are repelled by the cathode and attracted by

the anode, and under these conditions radiant matter should proceed from the anode. If oxygen were a solid it would block the current. Sulphur and selenium are non-conductors except in the positive allotropic form. Here the question is raised: What change occurs in the relation of these elements to the electric current concurrently with their qualitative transformation? We have stated that the forces in electric currents favor a rapid negative and a slow positive movement. When the gap is filled by a solid element of negative quality, such as sulphur, the potential at the cathode repels the sulphur molecule, and thus there is a block, a molecule cannot be electrically loaded except by attraction; at the anode the positive ether unites with the sulphur molecule, and if the latter were volatile it would be carried along as radiant matter; but the concentrativeness of positive ether, and its association with the negative sulphur prevent the positive ether from being handed over to the next sulphur molecule in line. As the positive ether has no repelling force, and as the attractive force between the negative ether and the positive is weakened by the length of the gap, there is also a block at the anode.

When a positive element, as a metal, or electropositive sulphur, is placed within the circuit the negative ether attracts the initiatory molecule of the medium, and, as repulsion is inherent in negative ether, the loaded molecule is repelled, thus the current is effected by the trapeziform vibratory movement; and if the circuit is uniformly positive the entire current will be negative. At the anode the initiatory molecule (under certain resistances) may be positively charged and then attracted to the cathode, but the current will be relatively weak, owing to the absence of a repulsive force

How is it that positive elements possess the property of conduction in a different degree? When a strong chemical element, such as zinc, forms part of an electric circuit, the negative ether unites with it with a stronger force than it does when a weaker chemical element, as copper, forms the conducting element. Clearly dissociation requires a stronger force with zinc as a conductor than when copper is the medium. The dissociating and propelling force is the negative diffusibility, and it is weakened by zinc having larger intermolecular spaces, the force being inversely proportional to the square of distance. When a positive molecule is charged negatively its inductive potential and hence its induced field must be neutralized; consequently the elasticity and impenetrability of the field are lost. It follows that the amount of electricity carried over by a vibration must be directly proportional to the inductive potential of the vibratory molecule.

From these considerations it may be formulated: That electric conduction by molecular vibration in a medium uniformly composed of electro-positive material is effected by alternate association and dissociation between the conducting molecules and negative atomic ether; that the property of conduction is enhanced by an increase of the positive potential of the conducting molecule up to a certain maximum; and that beyond this maximum the property is depreciated by a greater dissociating force being requisite. In addition, as during association neutralization of the inductive potential of the molecule, with a concurrent modification of the intermolecular space, must occur, it is obvious that the larger the intermolecular space the more will be the molecular relational disturbance, and interference with the vibratory adjustment. From these elements the

molecular vibratory balance is constructed, the delicate equipoise of which is essential to the best type of an electric conductor. In the electric conductor each molecule takes on and gives off an atom of ether (or more) with each vibration; and this is accomplished (in metals at least) without any permanent change in the constitution of the molecule, although various chips are torn off from electrodes. In the radio-active substance each molecule takes on and gives off atomic ether with each vibration; but additionally it also associates and dissociates a chip (the attraction between the chip and the ether being greater than between the chip and the radio-active molecule), but the gain is equal to the loss and the molecular constituency remains the same. Like electric conduction, radio-activity must depend upon a molecular vibratory balance as its chief actor.

Conclusions are inevitable: That we live in an atmosphere of chipchens; that they are a factor of the atmospheric pressure, and under certain conditions give distinctive pressure; that they enter our respiratory tracks, may remain in the induced fields of the oxygen and thus circulate in the blood, and may have valuable physiological properties; that they enter into various chemical combinations and modify the physical properties of matter; that they associate with other elements in crystallization—the chipchens of crystallization; that they associate with and dissociate from other elements during radio-activity, and possibly during magnetization; that they constitute radiant matter, which penetrates the interspaces of so-called opaque substances, and may be the excitants to the nerves of smell; that as radiant matter they are carriers of electricity, and by chemical union with non-conductors may

render the latter electric vibratory conductors; that within the molecular interspaces they are relatively inactive, being in equilibrium, but acquire an intense chemical activity in direct proportion to their kinetic potentials; and that when kinetically and chemically active, they have the property of potentially and qualitatively modifying cells, and hence may have a destructive and constructive therapeutic value.

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